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| <p>(21) International Application Number: PCT/US96/11131</p> <p>(22) International Filing Date: 28 June 1996 (28.06.96)</p> <p>(30) Priority Data: 60/000,747 30 June 1995 (30.06.95) US 08/671,392 27 June 1996 (27.06.96) US</p> <p>(60) Parent Applications or Grants (63) Related by Continuation US 60/000,747 (CON) Filed on 30 June 1995 (30.06.95) US 08/671,392 (CON) Filed on 27 June 1996 (27.06.96)</p> <p>(71) Applicant (<i>for all designated States except US</i>): E.I. DU PONT DE NEMOURS AND COMPANY [US/US]; 1007 Market Street, Wilmington, DE 19898 (US).</p> <p>(72) Inventors; and (75) Inventors/Applicants (<i>for US only</i>): JOHNSON, Lynda, Kaye [US/US]; Apartment 5B2, 402 Foulk Road, Wilmington, DE 19803 (US). FELDMAN, Jerald [US/US]; 16 Cinnamon Drive, Hockessin, DE 19707-1349 (US). KREUTZER, Kristina, Ann [US/US]; Apartment 2C, 4 Doe Run Court,</p> | | <p>Wilmington, DE 19808-2059 (US). MCLAIN, Stephan, James [US/US]; 202 Old Mill Lane, Wilmington, DE 19803-4922 (US). BENNETT, Alison, Margaret, Anne [GB/US]; 507 Falkirk Road, Wilmington, DE 19803 (US). COUGHLIN, Edward, Bryan [US/US]; Apartment E, 2227 Prior Road, Wilmington, DE 19809-1154 (US). DONALD, Dennis, Scott [US/US]; P.O. Box 321, Mendenhall, PA 19357-0321 (US). NELSON, Lissa, Taka, Jennings [US/US]; Apartment H-8, 3131 Meetinghouse Road, Boothwyn, PA 19061 (US). PARTHASARATHY, Anju [US/US]; 1562 Pottstown Pike, Glenmoore, PA 19343-9614 (US). SHEN, Xing [CN/US]; 4043D Miramar Street, La Jolla, CA 92037 (US). TAM, Wilson [US/US]; 3781 Brookcroft Lane, Boothwyn, PA 19061-1817 (US). WANG, Yueli [CN/US]; 238 Presidential Drive #B, Wilmington, DE 19807 (US).</p> <p>(74) Agent: EVANS, Craig, H.; E.I. du Pont de Nemours and Company, Legal Patent Records Center, 1007 Market Street, Wilmington, DE 19898 (US).</p> <p>(81) Designated States: AL, AM, AU, AZ, BB, BG, BR, BY, CA, CN, CZ, EE, GE, HU, IL, IS, JP, KG, KP, KR, KZ, LK, LR, LT, LV, MD, MG, MK, MN, MX, NO, NZ, PL, RO, RU, SG, SI, SK, TJ, TM, TR, TT, UA, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> | |
| <p>Published <i>With international search report.</i></p> <p>(54) Title: OLEFIN POLYMERIZATION PROCESS</p> <p>(57) Abstract</p> <p>Disclosed herein is a process for the polymerization of ethylene, norbornenes and styrenes, by contacting in solution a selected nickel compound and a selected compound which is or can be coordinated to the nickel with the olefin(s). The polymers produced are useful for films and molding resins.</p> | | | |

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TITLE

OLEFIN POLYMERIZATION PROCESS

This application is a continuation-in-part of United States Provisional Application Serial No. 60/000,747, filed June 30, 5 1995.

FIELD OF THE INVENTION

This invention concerns a process for the preparation of polyolefins by coordination polymerization of ethylene, styrene or norbornene by a nickel compound coordinated to a selected ligand.

TECHNICAL BACKGROUND

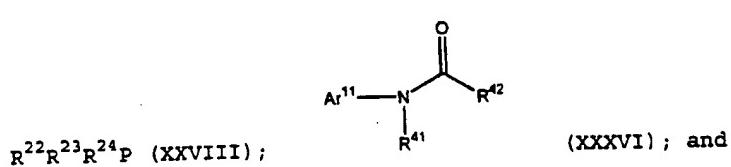
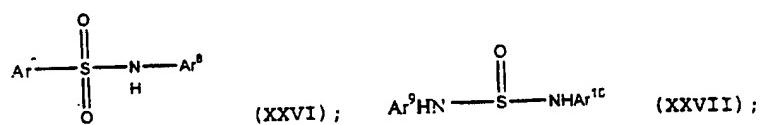
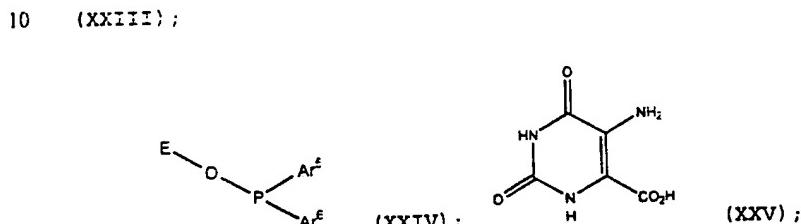
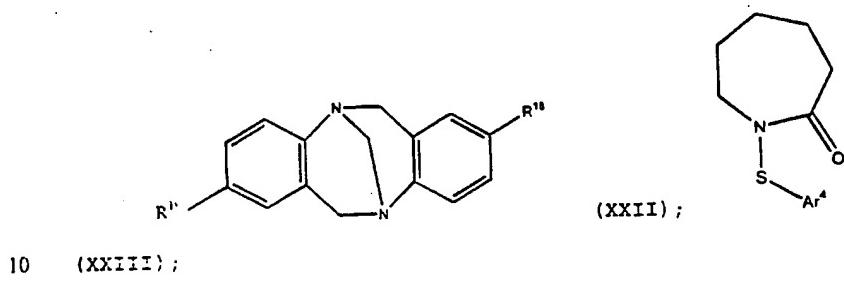
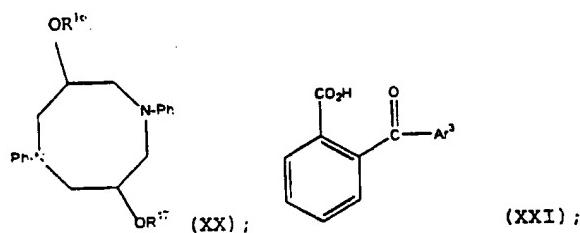
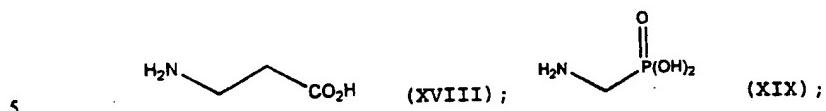
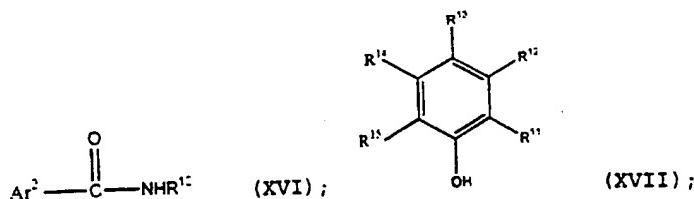
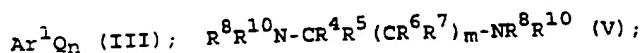
10 Polyolefins are very important items of commerce, being used for myriad uses, such as molding resins, films, ropes, composites, fibers, elastomers, etc. Suitability for any particular use is dependent on the polymer properties, for instance whether the 15 polymer is elastomeric or thermoplastic. One method of polymerization of these olefins is by coordination polymerization, use of a polymerization catalyst containing a transition metal, the metal usually being thought of as coordinating to one or more species during the polymerization process.

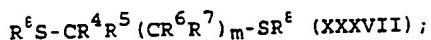
20 Whether any particular transition metal compound is an olefin polymerization catalyst usually depends on the metal chosen and what is coordinated (such as various ligands) to the metal before and during the polymerization. Various transition metal compounds may or may not be active catalysts for a particular 25 (type of) olefin, and the resulting polymer structures may vary. Other factors such as the efficiency and rate of polymerization may vary. Therefore, new transition metal catalysts for olefin polymerizations are constantly being sought.

SUMMARY OF THE INVENTION

30 This invention concerns a process for the polymerization of an olefin, comprising:

(a) contacting a polymerizable monomer consisting essentially of ethylene, a norbornene or a styrene, and a catalyst system comprising the product of mixing in solution a zerovalent 35 tricoordinate or tetracoordinate nickel compound (II) which has at least one labile ligand, and all ligands are neutral, an acid of the formula HX (IV), and a first compound selected from the group consisting of:





wherein:

X is a noncoordinating anion;

Ar¹ is an aromatic moiety with n free valencies, or

5 diphenylmethyl;

each Q is -NR²R⁴³ or -CR⁹=NR³;

n is 1 or 2;

E is 2-thienyl or 2-furyl;

each R² is independently hydrogen, benzyl, substituted

10 benzyl, phenyl or substituted phenyl;

each R⁹ is independently hydrogen or hydrocarbyl; and

each R³ is independently a monovalent aromatic moiety;

m is 1, 2 or 3;

R⁴³ is hydrogen or alkyl;

15 each R⁴, R⁵, R⁶, and R⁷ is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

each R⁸ is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

each R¹⁰ is independently hydrogen, hydrocarbyl or

20 substituted hydrocarbyl;

Ar² is an aryl moiety;

R¹², R¹³, and R¹⁴ are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

R¹¹ and R¹⁵ are each independently hydrocarbyl,

25 substituted hydrocarbyl or an inert functional group whose E_s is about -0.4 or less;

each R¹⁶ and R¹⁷ is independently hydrogen or acyl containing 1 to 20 carbon atoms;

Ar³ is an aryl moiety;

30 R¹⁸ and R¹⁹ are each independently hydrogen or hydrocarbyl;

Ar⁴ is an aryl moiety;

Ar⁵ and Ar⁶ are each independently hydrocarbyl;

Ar⁷ and Ar⁸ are each independently an aryl moiety;

35 Ar⁹ and Ar¹⁰ are each independently an aryl moiety or -CO₂R²⁵, wherein R²⁵ is alkyl containing 1 to 20 carbon atoms;

Ar¹¹ is an aryl moiety;

R⁴¹ is hydrogen or hydrocarbyl;

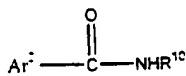
R^{42} is hydrocarbyl or $-C(O)-NR^{41}-Ar^{11}$;

R^{44} is aryl;

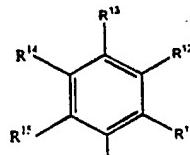
R^{22} and R^{23} are each independently phenyl groups
5 substituted by one or more alkoxy groups, each alkoxy group
containing 1 to 20 carbon atoms; and
 R^{24} is alkyl containing 1 to 20 carbon atoms, or an aryl
moiety.

This invention also concerns a catalyst for the
10 polymerization of ethylene, a norbornene, or a styrene,
comprising, the product of mixing in solution a zerovalent
tricoordinate or tetracoordinate nickel compound (II) which has at
least one labile ligand and all ligands are neutral, an acid of
the formula HX (IV), and a compound selected from the group
15 consisting of:

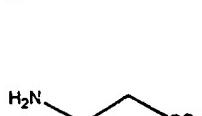
Ar^1Q_n (III); $R^8R^{10}N-CR^4R^5(CR^6R^7)_m-NR^8R^{10}$ (V);



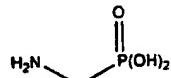
(XVI);



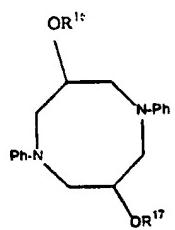
(XVII);



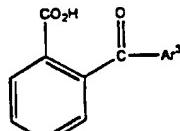
(XVIII);



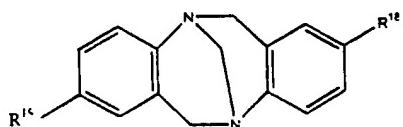
(XIX);



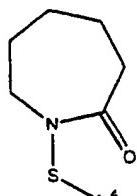
(XX);



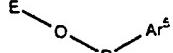
(XXI);



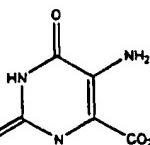
(XXII);



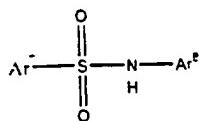
(XXIII);



(XXIV);



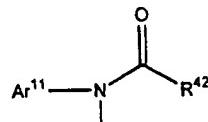
(XXV);



(XXVI);



(XXVII);



(XXXVI);

 $R^{22}R^{23}R^{24}P$ (XXVIII);and $R^E-S-CR^4R^5(CR^6R^7)_m-SR^E$ (XXXVII);

10

wherein:

X is a noncoordinating anion;

Ar¹ is an aromatic moiety with n free valencies, or

diphenylmethyl;

each Q is $-NR^2R^4$ or $-CR^9=NR^3$;

15

n is 1 or 2;

E is 2-thienyl or 2-furyl;

 R^{43} is hydrogen or alkyl;each R^2 is independently hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl;20 each R^3 is independently a monovalent aromatic moiety;each R^9 is independently hydrogen or hydrocarbyl;

m is 1, 2 or 3;

each R^4 , R^5 , R^6 , and R^7 is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

each R^8 is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

each R^{10} is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

5 Ar^2 is an aryl moiety;

R^{12} , R^{13} , and R^{14} are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

R^{11} and R^{15} are each independently hydrocarbyl, substituted hydrocarbyl or an inert functional group whose E_s is

10 about -0.4 or less;

each R^{16} and R^{17} is independently hydrogen or acyl containing 1 to 20 carbon atoms;

Ar^3 is an aryl moiety;

R^{18} and R^{19} are each independently hydrogen or

15 hydrocarbyl;

Ar^4 is an aryl moiety;

Ar^5 and Ar^6 are each independently hydrocarbyl;

Ar^7 and Ar^8 are each independently an aryl moiety;

Ar^9 and Ar^{10} are each independently an aryl moiety.

20 CO_2R^{25} , or Ar^7 and Ar^8 taken together are a divalent aromatic moiety and wherein R^{25} is alkyl containing 1 to 20 carbon atoms;

Ar^{11} is an aryl moiety;

R^{41} is hydrogen or hydrocarbyl;

R^{42} is hydrocarbyl or $-C(O)-NR^{41}-Ar^{11}$;

25 R^{44} is aryl;

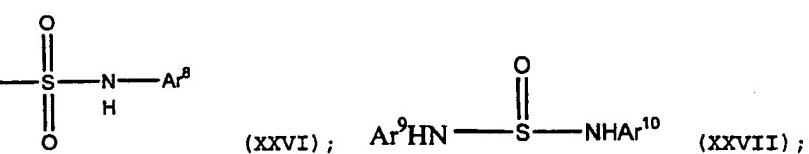
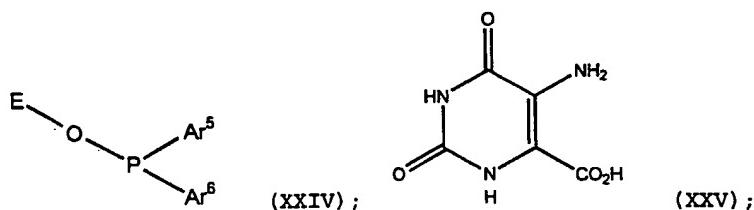
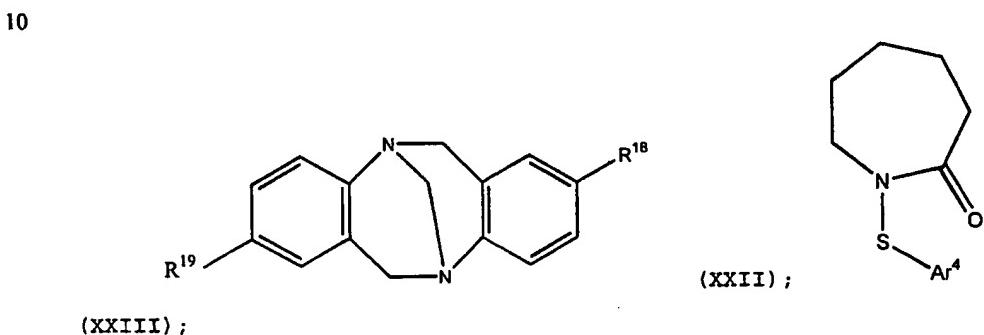
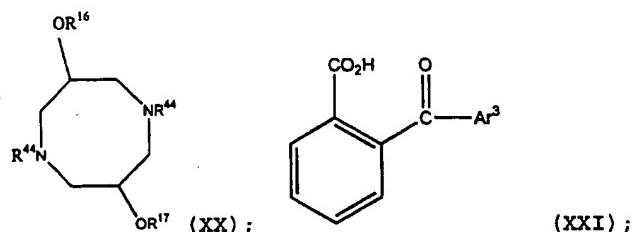
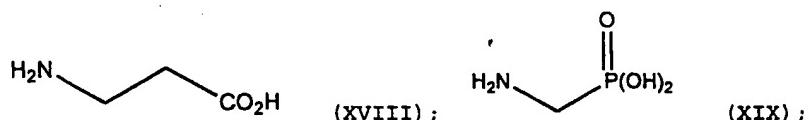
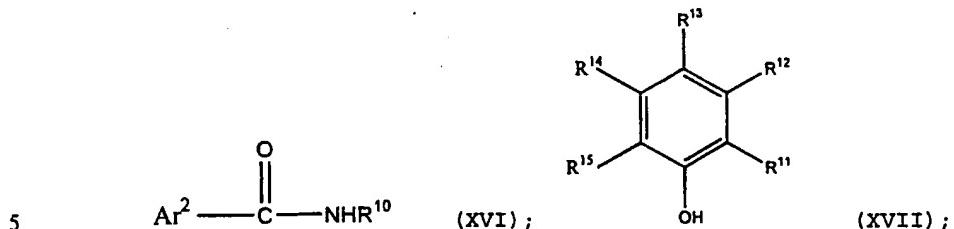
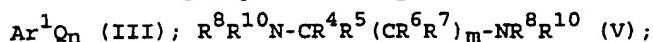
R^{22} and R^{23} are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and

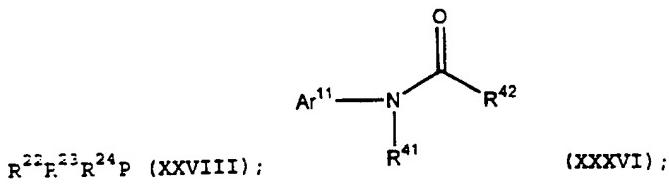
R^{24} is alkyl containing 1 to 20 carbon atoms, or an aryl moiety;

30 and provided that the molar ratio of (III), (V) (XVI), (XVII), (XVIII), (XIX), (XX), (XXI), (XXII), (XXIII), (XXIV), (XXV), (XXVI), (XXVII), (XXVIII), (XXXVI) or (XXXVII):(II) is about 0.5 to about 5, and the molar ratio of (IV):(II) is about 0.5 to about 10.

This invention also concerns a process for the polymerization of an olefin, comprising, contacting ethylene, a

norbornene, or a styrene with a nickel [II] complex of a ligand selected from the group consisting of:





wherein:

X is a noncoordinating anion;

5 Ar¹ is an aromatic moiety with n free valencies, or

diphenylmethyl;

each Q is -NR²R⁴³ or -CR⁹=NR³;

R⁴³ is hydrogen or alkyl;

n is 1 or 2;

10 E is 2-thienyl or 2-furyl;

each R² is independently hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl;

each R³ is independently a monovalent aromatic moiety;

each R⁹ is independently hydrogen or hydrocarbyl; m is

15 1, 2 or 3;

each R⁴, R⁵, R⁶, and R⁷ is independently hydrogen,

hydrocarbyl or substituted hydrocarbyl;

each R⁸ is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

20 each R¹⁰ is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

Ar² is an aryl moiety;

R¹², R¹³, and R¹⁴ are each independently hydrogen,

hydrocarbyl, substituted hydrocarbyl or an inert functional group;

25 R¹¹ and R¹⁵ are each independently hydrocarbyl, substituted hydrocarbyl or an inert functional group whose E_s is about -0.4 or less;

each R¹⁶ and R¹⁷ is independently hydrogen or acyl containing 1 to 20 carbon atoms;

30 Ar³ is an aryl moiety;

R¹⁸ and R¹⁹ are each independently hydrogen or

hydrocarbyl;

Ar⁴ is an aryl moiety;

Ar⁵ and Ar⁶ are each independently hydrocarbyl;

35 Ar⁷ and Ar⁸ are each independently an aryl moiety;

Ar^9 and Ar^{10} are each independently an aryl moiety, - CO_2R^{25} , or Ar^7 and Ar^6 taken together are a divalent aromatic moiety and wherein R^{25} is alkyl containing 1 to 20 carbon atoms;

Ar^{11} is an aryl moiety;

5 R^{41} is hydrogen or hydrocarbyl;

R^{42} is hydrocarbyl or $-\text{C}(\text{O})-\text{NR}^{41}-\text{Ar}^{11}$;

R^{44} is aryl;

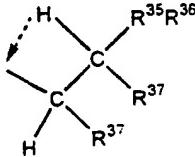
R^{22} and R^{23} are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and

10 R^{24} is alkyl containing 1 to 20 carbon atoms, or an aryl moiety.

Described herein is a process for the polymerization of olefins, comprising, contacting ethylene, a norbornene or a styrene with a nickel containing first compound of the formula [$\text{L}^1\text{sL}^2\text{rL}^3\text{sL}^4\text{tNi}$]⁺ X^- (XXXIII), wherein:

15 L^1 is a first monodentate neutral ligand coordinated to said nickel, L^2 is a second monodentate neutral ligand coordinated to said nickel which may be said first monodentate neutral ligand and r is 0 or 1, or L^1 and L^2 taken together are a first bidentate neutral ligand coordinated to said nickel and r is 1;

20 L^3 and L^4 taken together are a π -allyl ligand coordinated to said nickel, L^3 and L^4 taken together are



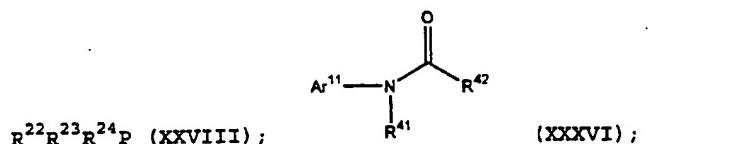
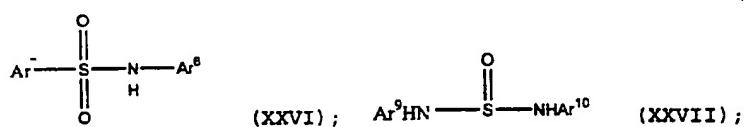
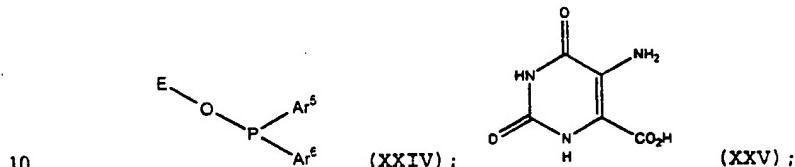
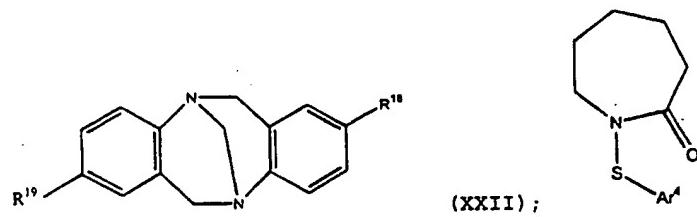
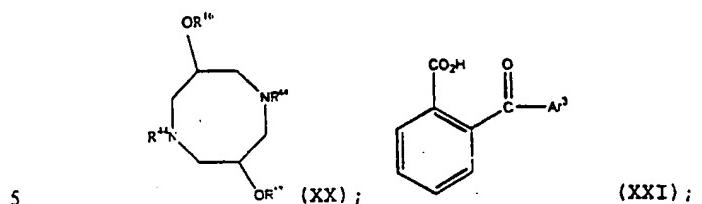
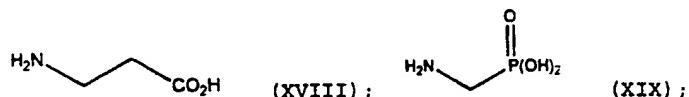
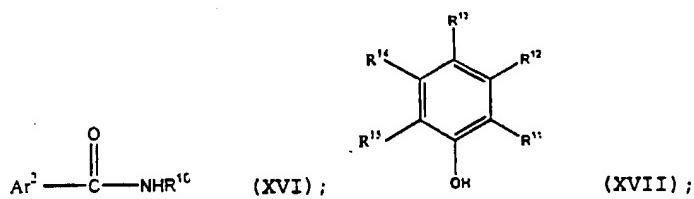
(XXXII)

25 coordinated to said nickel, or L^3 is a third neutral monodentate ligand selected from the group consisting of ethylene, a norbornene and a styrene or a neutral monodentate ligand which can be displaced by an olefin, and L^4 is R^{38} ;

30 X is a relatively non-coordinating anion;

 each of q , s and t is 1;

 said first monodentate neutral ligand and said first bidentate neutral ligand are selected from the group consisting of Ar^1Q_n (III); $\text{R}^8\text{R}^{10}\text{N}-\text{CR}^4\text{R}^5(\text{CR}^6\text{R}^7)_m-\text{NR}^8\text{R}^{10}$ (V);



15 and $R^8S-CR^4R^5(CR^6R^7)_m-SR^8$ (XXXVII);
 Ar¹ is an aromatic moiety with n free valencies, or
 diphenylmethyl;

each Q is $-NR^2R^{43}$ or $-CR^9=NR^3$;
R⁴³ is hydrogen or alkyl;
n is 1 or 2;

E is 2-thienyl or 2-furyl;

5 each R² is independently hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl;

each R⁹ is independently hydrogen or hydrocarbyl; and
each R³ is independently a monovalent aromatic moiety;

m is 1, 2 or 3;

10 each R⁴, R⁵, R⁶, and R⁷ is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

each R⁸ is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

each R¹⁰ is independently hydrogen, hydrocarbyl or

15 substituted hydrocarbyl;

Ar² is an aryl moiety;

R¹², R¹³, and R¹⁴ are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

R¹¹ and R¹⁵ are each independently hydrocarbyl,

20 substituted hydrocarbyl or an inert functional group whose E_s is about -0.4 or less;

each R¹⁶ and R¹⁷ is independently hydrogen or acyl containing 1 to 20 carbon atoms;

Ar³ is an aryl moiety;

25 R¹⁸ and R¹⁹ are each independently hydrogen or hydrocarbyl;

Ar⁴ is an aryl moiety;

Ar⁵ and Ar⁶ are each independently hydrocarbyl;

Ar⁷ and Ar⁸ are each independently an aryl moiety;

30 Ar⁹ and Ar¹⁰ are each independently an aryl moiety or $-CO_2R^{25}$, wherein R²⁵ is alkyl containing 1 to 20 carbon atoms;

Ar¹¹ is an aryl moiety;

R⁴¹ is hydrogen or hydrocarbyl;

R⁴² is hydrocarbyl or $-C(O)-NR^{41}-Ar^{11}$;

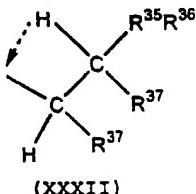
35 R²² and R²³ are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and

R^{24} is alkyl containing 1 to 20 carbon atoms, or an aryl moiety;
 R^{35} is hydrocarbylene;
 R^{36} is hydrogen, alkyl, or $-C(O)R^{39}$;
5 each R^{37} is hydrocarbyl or both of R^{37} taken together are hydrocarbylene to form a carbocyclic ring;
 R^{38} is hydride, alkyl or $-C(O)R^{39}$; and
 R^{39} is hydrocarbyl
 R^{44} is aryl.

10

Also described herein is a compound of the formula $[L^1_q L^2_s L^3_t L^4_r Ni]^{+} X^{-}$ (XXXIII), wherein:
 L^1 is a first monodentate neutral ligand coordinated to said nickel, L^2 is a second monodentate neutral ligand coordinated to said nickel which may be said first monodentate neutral ligand and r is 0 or 1, or L^1 and L^2 taken together are a first bidentate neutral ligand coordinated to said nickel and r is 1;

15 L^3 and L^4 taken together are a π -allyl ligand coordinated to said nickel, L^3 and L^4 taken together are

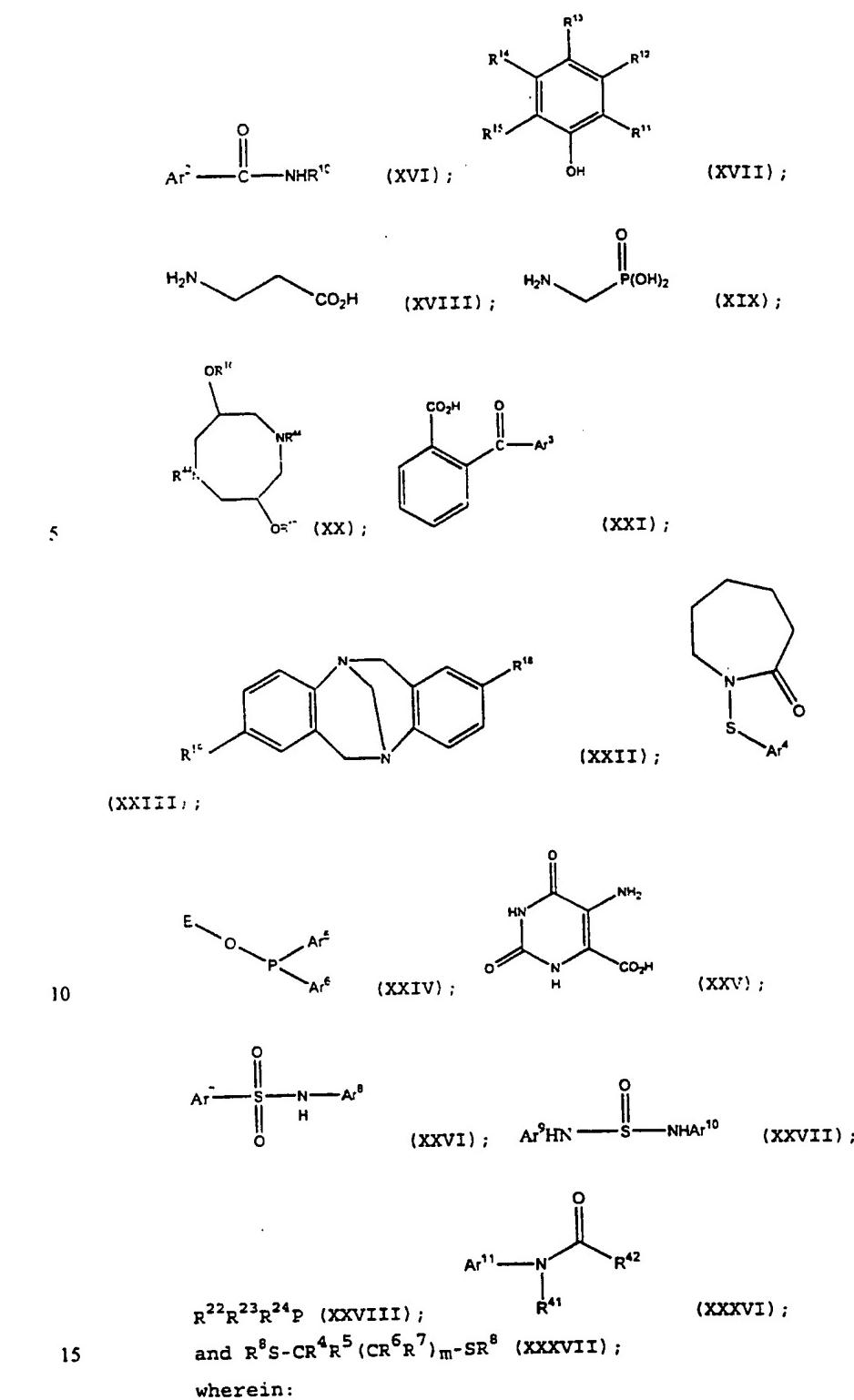


20

coordinated to said nickel, or L^3 is a third neutral monodentate ligand selected from the group consisting of ethylene, a norbornene and a styrene or a neutral monodentate ligand which can be displaced by an olefin, and L^4 is R^{38} ;

25 X is a relatively non-coordinating anion;
 q , s and t are each 1;
 L^1 and L^2 are selected from the group consisting of said first monodentate neutral ligand and said first bidentate neutral ligand are selected from the group consisting of

30 $Ar^1 Q_n$ (III); $R^8 R^{10} N-CR^4 R^5 (CR^6 R^7)_m-NR^8 R^{10}$ (V);



Ar^1 is an aromatic moiety with n free valencies, or
 diphenylmethyl;
 each Q is $-\text{NR}^2\text{R}^{43}$ or $-\text{CR}^9=\text{NR}^3$;
 R^{43} is hydrogen or alkyl;
 5 n is 1 or 2;
 E is 2-thienyl or 2-furyl;
 each R^2 is independently hydrogen, benzyl, substituted
 benzyl, phenyl or substituted phenyl;
 each R^9 is independently hydrogen or hydrocarbyl; and
 10 each R^3 is independently a monovalent aromatic moiety;
 m is 1, 2 or 3;
 each R^4 , R^5 , R^6 , and R^7 is independently hydrogen,
 hydrocarbyl or substituted hydrocarbyl;
 each R^8 is independently hydrocarbyl or substituted
 15 hydrocarbyl containing 2 or more carbon atoms;
 each R^{10} is independently hydrogen, hydrocarbyl or
 substituted hydrocarbyl;
 Ar^2 is an aryl moiety;
 R^{12} , R^{13} , and R^{14} are each independently hydrogen,
 20 hydrocarbyl, substituted hydrocarbyl or an inert functional group;
 R^{11} and R^{15} are each independently hydrocarbyl,
 substituted hydrocarbyl or an inert functional group whose E_b is
 about -0.4 or less;
 each R^{16} and R^{17} is independently hydrogen or acyl
 25 containing 1 to 20 carbon atoms;
 Ar^3 is an aryl moiety;
 R^{18} and R^{19} are each independently hydrogen or
 hydrocarbyl;
 Ar^4 is an aryl moiety;
 30 Ar^5 and Ar^6 are each independently hydrocarbyl;
 Ar^7 and Ar^8 are each independently an aryl moiety;
 Ar^9 and Ar^{10} are each independently an aryl moiety or
 $-\text{CO}_2\text{R}^{25}$, wherein R^{25} is alkyl containing 1 to 20 carbon atoms;
 Ar^{11} is an aryl moiety;
 35 R^{41} is hydrogen or hydrocarbyl;
 R^{42} is hydrocarbyl or $-\text{C}(\text{O})-\text{NR}^{41}-\text{Ar}^{11}$;
 R^{44} is aryl;

R^{22} and R^{23} are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and

5 R^{24} is alkyl containing 1 to 20 carbon atoms, or an aryl moiety;

R^{35} is hydrocarbylene;

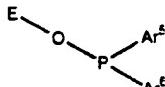
R^{36} is hydrogen, alkyl, or $-C(O)R^{39}$;

10 each R^{37} is hydrocarbyl or both of R^{37} taken together are hydrocarbylene to form a carbocyclic ring;

R^{38} is hydride, alkyl or $-C(O)R^{39}$; and

R^{39} is hydrocarbyl.

Described herein is a compound of the formula



(XXIV)

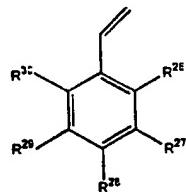
15 wherein:

E is 2-thienyl or 2-furyl;

Ar^5 and Ar^6 are each independently hydrocarbyl.

DETAILS OF THE INVENTION

20 The olefins polymerized herein are ethylene, a styrene and a norbornene. Norbornene and styrene may be present in the same polymerization, and a copolymer may be produced. By a styrene herein is meant a compound of the formula

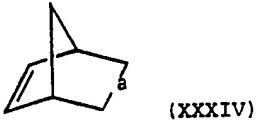


25 (XXIX)

wherein R^{26} , R^{27} , R^{28} , R^{29} and R^{30} are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or a functional group, all of which are inert in the polymerization process. It is preferred that all of R^{26} , R^{27} , R^{28} , R^{29} and R^{30} are hydrogen.

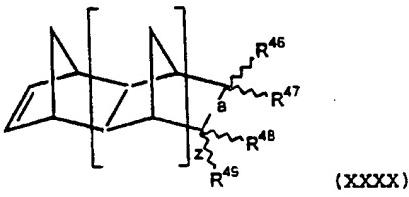
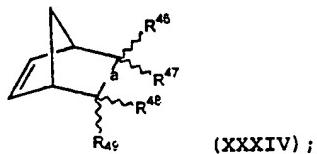
30 By "a norbornene" is meant that the monomer is characterized by containing at least one norbornene-functional group in its

structure including norbornadiene as identified by the formulas below, which can be substituted or unsubstituted



wherein "a" represents a single or double bond.

5 Representative monomers are compounds (XXXV) and (XXXX) as follows:



wherein R⁴⁶, R⁴⁷, R⁴⁸, and R⁴⁹ independently are hydrogen halogen, or hydrocarbyl, provided that, except if the hydrocarbyl group is vinyl, if any of the hydrocarbyl are alkenyl, there is no terminal double bond, i.e., the double bond is internal; or R⁴⁶ and R⁴⁸ taken together can be part of carbocyclic ring (saturated, unsaturated or aromatic); or R⁴⁶ and R⁴⁷ and/or R⁴⁸ and R⁴⁹ taken together are an alkylidene group. In these structures "z" is 1 to

15 5.

Examples of such norbornenes include norbornadiene, 2-norbornene, 5-methyl-2-norbornene, 5-hexyl-2-norbornene, 5-ethylidene-2-norbornene, vinylnorbornene, dicyclopentadiene, dihydrodicyclopentadiene, tetracyclododecene, trimers of cyclopentadiene, halogenated norbornenes wherein R⁴⁶, R⁴⁷, R⁴⁸ and R⁴⁹ may also be halogen or fully halogenated alkyl groups such as C_wF_{2w+1}, wherein w is 1 to 20, such as perfluoromethyl and perfluorodecyl.

The halogenated norbornenes can be synthesized via the
25 Diels-Alder reaction of cyclopentadiene an appropriate

dieneophile, such as $F_3CC\equiv CCF_3$ or $R^{49}C=C R^{49}C_wF_{2w+1}$ wherein each R^{49} is independently hydrogen or fluorine and w is 1 to 20.

It is also preferred that in the polymerization processes described herein that the polymer produced has an average degree of polymerization of about 10 or more, more preferably about 20 or more, and especially preferably about 50 or more.

In the polymerization processes and catalyst compositions described herein certain groups may be present. By hydrocarbyl is meant a univalent radical containing only carbon and hydrogen. By saturated hydrocarbyl is meant a univalent radical which contains only carbon and hydrogen, and contains no carbon-carbon double bonds, triple bonds and aromatic groups. By substituted hydrocarbyl herein is meant a hydrocarbyl group which contains one or more (types of) substituents that does not interfere with the operation of the polymerization catalyst system. Suitable substituents include halo, ester, keto (oxo), amino, imino, carboxyl, phosphite, phosphonite, phosphine, phosphinite, thioether, amide, nitrile, and ether. Preferred substituents are halo, ester, amino, imino, carboxyl, phosphite, phosphonite, phosphine, phosphinite, thioether, and amide. By benzyl is meant the $C_6H_5CH_2-$ radical, and substituted benzyl is a radical in which one or more of the hydrogen atoms is replaced by a substituent group (which may include hydrocarbyl). By phenyl is meant the C_6H_5- radical, and a phenyl moiety or substituted phenyl is a radical in which one or more of the hydrogen atoms is replaced by a substituent group (which may include hydrocarbyl). Preferred substituents for substituted benzyl and phenyl include those listed above for substituted hydrocarbyl, plus hydrocarbyl. If not otherwise stated, hydrocarbyl, substituted hydrocarbyl and all other groups containing carbon atoms, such as alkyl, preferably contain 1 to 20 carbon atoms.

By an aromatic moiety herein is meant a radical containing at least one carbocyclic or heterocyclic aromatic ring, which has a number of free valences to the carbon atoms of the aromatic carbocyclic ring(s). A monovalent aromatic moiety has one free valence, and herein is termed an aryl moiety. If there is more than one aromatic ring in the radical, the ring may be joined by covalent bonds (as in biphenyl) or may be fused (as in

naphthalene), or both. The free valencies may be at carbon atoms in one ring, or more than one ring if more than one ring is present. The aromatic ring(s) may be substituted by hydrocarbyl groups or other substitutents which don't interfere with the catalytic activity of the catalyst system. Substituents that aid the polymerization may be present. Suitable and preferred substituents are as listed above for substituted hydrocarbyl groups. Suitable aromatic radicals herein include phenyl, o-phenylene, 1,8-naphthylene, and 2-thiophenyl.

10 A transition metal compound which may be initially added to a polymerization process mixture is (II), a zerovalent nickel compound which is tricoordinate or tetracoordinate. Also included within the definition of this zerovalent nickel compound are mixtures of compounds which will generate suitable zerovalent 15 nickel compounds *in situ*, such as mixtures of nickel compounds in higher valence states with suitable reducing agents. The ligands which are coordinated to the nickel atom may be monodentate or polydentate, so long as the nickel compound is tricoordinate or tetracoordinate. The ligands should be such that at least two, 20 and preferably all, of the coordination sites of the nickel atom are coordinated to ligands which are readily, reversibly or irreversibly, displaceable by (III), (V), or any one of (XVI) to (XIX), (XXXVI) and (XXXVII). Such readily displaceable ligands include η^4 -1,5-cyclooctadiene and tris(o-tolyl)phosphite (which is 25 a phosphite with a large cone angle), ethylene and carbon monoxide. A preferred nickel compound (II) is bis(η^4 -1,5-cyclooctadiene)nickel[0].

By the compound HX is meant the acid of a noncoordinating monoanion, or the equivalent thereof, i.e., a combination of 30 compounds that will generate this acid. Noncoordinating anions are well known to the artisan, see for instance W. Beck., et al., Chem. Rev., vol. 88, p. 1405-1421 (1988), and S. H. Strauss, Chem. Rev., vol. 93, p. 927-942 (1993), both of which are hereby included by reference. Relative coordinating abilities of such 35 noncoordinating anions are described in these references, Beck at p. 1411, and Strauss at p. 932, Table III. Also useful in this process in place of HX are "solid" acids, such as acidic aluminas,

clays and zirconias, which are considered herein to be acids with relatively non-coordinating anions.

Preferred anions X are BF_4^- , PF_6^- , and BAF {tetrakis[3,5-bis(trifluoromethyl)phenyl]borate}, SbF_6^- , and BAF is especially preferred. The acids of these anions are known, for instance HBF_4 is commercially available, and HBAF can be made by the method described in M. Brookhart, et al., *Organometallics*, vol. 11, p. 3920-3922 (1992).

In all forms of (III) it is preferred that R^9 and R^{43} are hydrogen. If R^{43} is alkyl, it is preferred that it is methyl. In all forms of (III), each R^2 may be independently hydrogen, hydrocarbyl or substituted hydrocarbyl, and it is preferred that each R^2 is hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl.

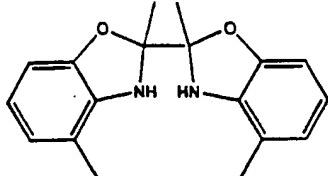
In one preferred form of (III), n is 1 and Q is $-\text{NR}^2\text{R}^{43}$. It is preferred that R^2 is hydrogen and that Ar^1 is 2,6-dialkylphenyl or amide, carboxy, or keto substituted phenyl. More preferably, Ar^1 is 2,6-diisopropylphenyl, 2-carbomoylphenyl, 2-carboxyphenyl, or 2-benzoylphenyl.

In another preferred form of (III), n is 2 and each Q is $-\text{NR}^2\text{R}^{43}$. In this instance it is more preferred that R^2 is hydrogen, and/or Ar^1 is o-phenylene or 1,8-naphthylene, and it is especially preferred that Ar^1 is 1,8-naphthylene.

In (III), when n is 1 and Q is $-\text{CR}^9=\text{NR}^3$, it is preferred that R^9 is hydrogen, and R^3 is preferably 2,6-dialkylphenyl, or amide, ester, carboxyl, keto, or halo substituted phenyl. More preferably, R^3 is 2,6-diisopropylphenyl, 2-carbomoylphenyl, 2-carbomethoxyphenyl, 2-carboxyphenyl, 1-fluoren-9-onyl, 1-anthraquinolyl, or pentafluorophenyl. Ar^1 is aryl, or halo, ester, amino, imino, carboxyl, phosphite, phosphonite, phosphine, phosphinite, ether, thioether, or amide substituted phenyl. More preferably, Ar^1 is diphenylmethyl, 9-anthracyanyl, 2-furanyl, 2-thiofuranyl, 2-phenolyl, or 2-hydroxy-naphthyl. When Ar^1 is diphenylmethyl, these tautomeric forms are believed to exist when these compounds are complexed to nickel.

When in (III) n is 2 and Q is $-\text{CR}^9=\text{NR}^3$, it is preferred that Ar^1 is p-phenylene, and that R^3 is 2,6-disubstituted phenyl in which the substitutents are halo, alkyl, or halo and alkyl.

In (III), when Q is $-NHR^2$, R^2 taken together with Ar^1 may form a carbocyclic or heterocyclic ring, as long as the atom of R^2 attached directly to the nitrogen atom is a saturated carbon atom. Thus another preferred compound (III) is



5

It will be noted that there are actually two amino groups in this compound that meet the criteria for Q. This is compound 105, below.

For (V) it is preferred that m is 1, all of R^4 , R^5 , R^6 , R^7 and R^{10} are hydrogen, and both of R^8 are 2,6-dialkylphenyl, especially 2,6-diisopropylphenyl, or cyclohexyl. In another preferred compound (V) m is 1, all of R^4 , R^5 , R^6 , and R^7 are hydrogen, both of R^8 are phenyl, and both of R^{10} are ethyl. In (V) too much or too little steric hindrance around the nitrogen atoms may cause a catalytic composition containing such a compound to be ineffective as an olefin polymerization catalyst.

In (XVI) is preferred that Ar^2 is phenyl, 2-pyridyl, or 3-hydroxyl-2-pyridyl, and/or R^{10} is hydrogen, phenyl, 2,6-diisopropylphenyl, 1-naphthyl, 2-methyl-1-naphthyl, or 2-phenylphenyl.

In (XVII) it is preferred that R^{12} and R^{14} are hydrogen, and/or R^{13} is hydrogen or t-butyl, and/or R^{11} and R^{15} are both t-butyl or both phenyl, and/or R^{11} is t-butyl and R^{15} is 2-hydroxy-3,5-di-t-butylphenyl. Note that when R^{15} is 2-hydroxy-3,5-di-t-butylphenyl the compound contains 2 phenolic hydroxy groups, both of which are sterically hindered.

The steric effect of various groupings has been quantified by a parameter called E_s , see R. W. Taft, Jr., J. Am. Chem. Soc., vol. 74, p. 3120-3128 (1952), and M.S. Newman, Steric Effects in Organic Chemistry, John Wiley & Sons, New York, 1956, p. 598-603. For the purposes herein, the E_s values are those described in these publications. If the value for E_s for any particular group is not known, it can be determined by methods described in these publications. For the purposes herein, the value of hydrogen is defined to be the same as for methyl. It is preferred that the

total E_s value for the ortho (or other substituents closely adjacent to the -OH group) substituents in the ring be about -1.5 or less, more preferably about -3.0 or less. Thus in a compound such as 2,4,6-tri-t-butylphenol only the E_s values for the 2 and 6 substituted t-butyl groups would be applicable.

In (XX) it is preferred that both R^{16} and R^{17} are hydrogen or that both are acyl. A preferred acyl group is $\text{CH}_3\text{C}(\text{O})-$.

In (XXI) it is preferred that Ar^3 is phenyl or substituted phenyl, more preferably phenyl.

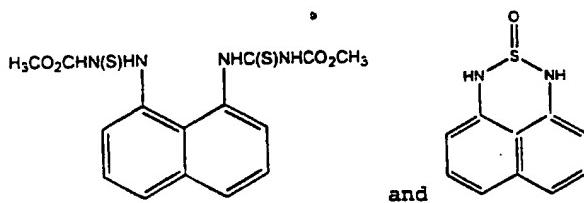
10 In (XXII) it is preferred that both of R^{18} and R^{19} are methyl, or both are hydrogen.

In (XXIII) it is preferred that Ar^4 is phenyl or substituted phenyl, more preferably phenyl.

15 In (XXIV) it is preferred that Ar^5 and Ar^6 are independently phenyl, substituted phenyl, or cyclohexyl, and it is especially preferred when both are cyclohexyl or both are phenyl.

20 In (XXVI) it is preferred that Ar^7 and Ar^8 are independently phenyl or substituted phenyl. In a specific preferred compound, Ar^7 is phenyl or p-tolyl and Ar^8 is 2,6-diisopropylphenyl.

In (XXVII) it is preferred that R^{25} is methyl. Specific preferred compounds are



25 Note that in one of these compounds there are 2 thiourea groups present.

In (XXVIII) it is preferred that R^{22} , R^{23} and R^{24} are each independently o-tolyl, 2,4,6-trimethoxyphenyl, 2,6-dimethoxyphenyl, 2-methoxyphenyl, and 2,3,6-trimethoxyphenyl.

30 Other preferred groups for R^{24} are ethyl, isopropyl and phenyl. It is also preferred that R^{24} is an aryl moiety. In another preferred form, when R^{22} , R^{23} and/or R^{24} are phenyl or substituted phenyl, there is at least one alkoxy group, preferably a methoxy

group, ortho (in the benzene ring) to the phosphorous atom. Another compound (XXVIII) is 1,3-bis[(bis-2,6-dimethoxyphenyl)phosphino]propane. This compound actually has two phosphine groups that each structurally meet the requirements for 5 a compound of type (XXVIII).

It is also preferred that each of R²², R²³, and R²⁴ (when it is an aryl moiety) contain electron donating groups bound to the aromatic moiety through a carbon atom of an aromatic ring. The concept of electron donating groups is well known to the artisan. 10 One method of measuring the electron donating ability of a group (particularly in a benzene ring, but it is not limited to such rings) which is not adjacent to the "active" center is by using the Hammett equation, see for instance H. H. Jaffe, Chem. Rev., vol. 53, p. 191-261 (1953). The actual result of this is called 15 the Hammett σ constant. For ortho (adjacent) substituents one may use the Taft σ^* constant as determined by measurements on ortho-benzoate esters, see for instance R. W. Taft, Jr., J. Am. Chem. Soc., vol. 74, p. 3120-3128 (1952); ibid., vol. 75, p. 4231-4238 (1953); and C. K. Ingold, Structure and Mechanism in Organic 20 Chemistry, 2nd Ed., Cornell University Press, Ithaca, 1969, p. 1220-1226. It is preferred that the total of the σ and σ^* constants for any of the groups R²², R²³, and R²⁴ (when it is an aryl moiety) be about -0.25 or less, more preferably about -0.50 or less (it is noted that the σ and σ^* constants for electron 25 donating groups are negative, so the more electron donating groups present, the more negative this total becomes) and especially preferably about -0.75 or less.

In (XXXVI) it is preferred that Ar¹¹ is 2,6-dialkylphenyl, more preferably 2,6-dimethylphenyl or 2,6-diisopropylphenyl. It is 30 preferred that R⁴² is -C(O)-NR⁴¹-Ar¹¹. It is preferred that R⁴¹ is hydrogen.

In (XXXVII) it is preferred that m is 1, and/or all of R⁴, R⁵, R⁶ and R⁷ are hydrogen, and/or both of R⁸ are aryl moieties, more preferably both of R⁸ are 2,6-dialkylphenyl, and especially 35 preferably both of R⁸ are 2,6-dimethylphenyl.

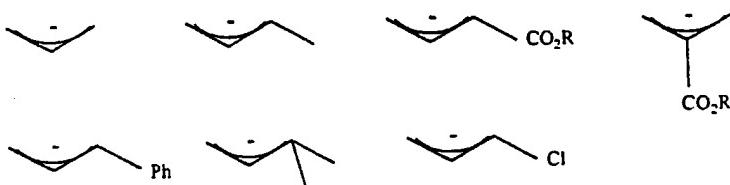
In some of the compounds herein, the group -CHPh₂, diphenylmethyl, may appear, especially when the methine carbon atom can be bound to the carbon atom of an imine. In this case

one can write such a compound as $-N=CH-CHPh_2$ (the imine form) or as $-NH-CH=CPh_2$ (amine form). It has been found that in the free compounds (not complexed to nickel) this group is usually in the amine form. However, in a few of the nickel complexes of these 5 types of compounds the preliminary evidence indicates the ligand is present in the imine form. Therefore, one may consider these forms interchangeable for the purposes herein, and it is noted that both types of compounds are mentioned in the claims herein.

The ligands can be made by methods that can be readily found 10 in the literature, and/or are available commercially or from laboratory supply houses, or are described in the Examples herein.

The polymerization may also be carried out by $[L^1_L^2_L^3_L^4Ni]^+X^-$ (XXXIII), which may be formed in situ or added directly to the initial polymerization mixture. For example, 15 (XXXIII) may be in the form of a π -allyl complex. By a π -allyl group is meant a monoanionic radical with 3 adjacent sp^2 carbon atoms bound to a metal center in an η^3 fashion. The three sp^2 carbon atoms may be substituted with other hydrocarbyl groups or functional groups. Typical π -allyl groups include

20



wherein R is hydrocarbyl. In (XXXIII) when it is a π -allyl type complex, L^3 and L^4 taken together are the π -allyl group. As shown 25 in many of the Examples herein, these π -allyl compounds may be stable, and may be used themselves to initiate the olefin polymerization.

Initiation with π -allyl compounds may be sluggish at times. Initiation of π -allyl compounds can be improved by using one or 30 more of the following methods:

- Using a higher temperature such as about 80°C.
- Decreasing the bulk of the ligand, such as R^2 and R^5 being 2,6-dimethylphenyl instead of 2,6-diisopropylphenyl.
- Making the π -allyl ligand more bulky, such as using



rather than the simple π -allyl group itself.

• Having a Lewis acid present while using a functional π -allyl. Relatively weak Lewis acids such a triphenylborane, tris(pentafluorophenyl)borane, and tris(3,5-trifluoromethylphenyl)borane, are preferred. Suitable functional groups include chloro and ester. "Solid" acids such as montmorillonite may also be used.

However, (XXXIII) may also be present in the polymerization 10 in other "forms". For instance, L^3 may be an olefin, such as ethylene, a norbornene or a styrene or a ligand capable of being displaced by an olefin. By a ligand capable of being displaced by an olefin is meant that the ligand is more weakly coordinating to nickel than an olefin, and when in the complex is in contact with 15 an olefin, the olefin displaces it. Such ligands are known in the art and include dialkyl ethers, tetrahydrofuran and nitriles such as acetonitrile.

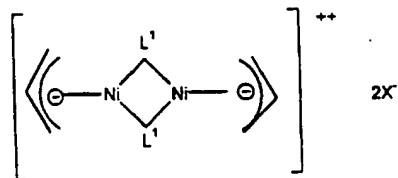
When L^3 is an olefin, L^4 may be $-R^{35}R^{36}$. R^{35} is alkylene, but it actually is a "polymeric" fragment with one or more repeat 20 units (derived from the olefin(s) being polymerized) making up R^{35} . In this form (XXXIII) may be said to be a living ended polymer, further polymerization adding more repeat units to R^{35} . R^{36} may be thought of as the end group of the polymeric group R^{35} , and may be derived from the similar grouping such as R^{38} which was 25 originally coordinated to the nickel.

When L^3 and L^4 in (XXXIII) taken together are (XXXII), (XXXIII) may also be thought of as a living polymer. This type of grouping is often referred to as an "agostic" coordination, and in 30 this group $-R^{35}R^{36}$ may be thought of in the same way as described above. Whether a living ended molecule will be in a form with a coordinated olefin or contain (XXXII) will depend on the other ligands coordinated to nickel, and the nature of the olefin being polymerized. It is believed that cyclic olefins tend to have living ends containing agostic groupings.

35 In (XXXIII) it is preferred that r is 1. The second monodentate neutral ligand may be any ligand which fits this description, including being the same as the first neutral monodentate ligand. Oftentimes though this ligand is a dialkyl

ether such as diethyl ether or an aliphatic nitrile such as acetonitrile, or tetrahydrofuran. By "neutral" in the context of (XXXIII) is meant that the ligand is electrically neutral, i.e., is not charged. In (XXXIII) preferred structures for the first 5 neutral monodentate ligand are those shown above. However, in certain circumstances, L¹ and L² may be a single neutral bidentate ligand of the same formula as when L¹ is a neutral monodentate ligand. In other words, some of the compounds (III), (V), (XVI) to (XXVIII), (XXXVI) and (XXXVII) may act as bidentate ligands in 10 (XXXIII). This may depend on the ligand itself, what the ratio of ligand to Ni is, what the other ligands may be, and whether there are any other compounds present which may also act as ligands.

When r in (XXXIII) is zero, simple dimers (containing 2 Ni atoms) with bridging ligands of the compound [L¹L³L⁴Ni]⁺X⁻ are 15 also included within the definition of (XXXIII). For instance a dimer containing L¹, r is zero, and L³ and L⁴ are combined into an π -allyl group could have the formula



In this structure both L¹ ligands are bridging between the 2 20 nickel atoms. This type of dimer is familiar to those skilled in the art, and is believed to readily disassociate into "monomeric" nickel compounds on exposure to olefin.

Some of the forms of (XXXIII) are relatively unstable, and are difficult to isolate as pure compounds. Nevertheless their 25 presence can be demonstrated by various methods known in the art. For instance, "living end" and other forms of (XXXIII) may be detected in solution by nuclear magnetic resonance (NMR) analysis, especially a combination of ¹H and ¹³C NMR. Such detection of living ends is usually best done when R³⁵ contains relatively few 30 repeat units.

(XXXIII) may be made by methods described herein, especially in the Examples, or may actually be formed in situ at the beginning of or during the polymerization process. It is believed that when (III), (V), (XVI) to (XXVIII), (XXXVI) or (XXXVII), and

(II) and HX are mixed together in solution a coordination compound such as (XXXIII) is formed which is active as a catalyst for the polymerization of olefins.

The preparation of one of the catalyst systems, when (II) is used, may be carried out in solution. By solution is meant that (II) and (III), (V), (XVI) to (XIX), (XXXVI) or (XXXVII), and (IV) are at least initially somewhat soluble in the solvent chosen. By somewhat soluble is meant that at least a 0.01 molar solution of each of the components in the solvent may be formed under process conditions. This catalyst system may then be removed from the solvent, as by evaporation of the solvent under vacuum, and then contacted with one or more olefins to carry out the polymerization. However, it is preferred to carry out the polymerization in the presence of the "original" solvent in which the active catalyst is formed. One or more of the components, including the polymer product, may become insoluble as the polymerization proceeds. Useful solvents include hydrocarbons such as toluene or benzene. Benzene is a preferred solvent. The benzene used herein is benzene-d₆.

Although it is not critical, when (II) is present it is preferred that the molar ratio of (III), (V), (XVI) to (XXVIII), (XXXVI) or (XXXVII):(II) is about 0.5 to 5, and the molar ratio of (IV):(II) is about 0.5 to about 10. It is also preferred that all the polymerizations be carried out at a temperature of about -100°C to about +200°C, more preferably about -20°C to about +100°C.

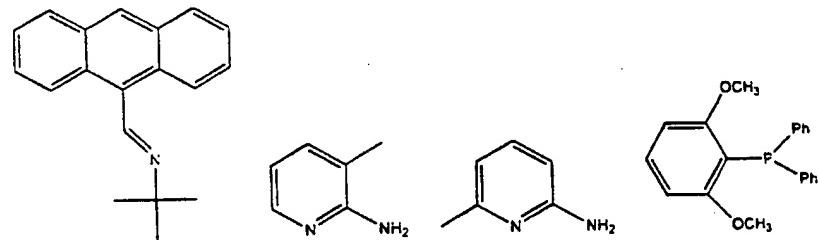
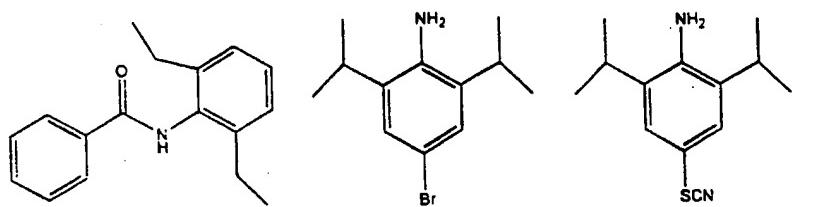
The polymers produced by this process are useful as molding resins, films and elastomers.

Most of the formulas for (III), (V), (XVI) to (XXVIII), (XXXVI) and (XXXVII) are generic formulas and embrace a wide range of actual compounds. The ability of such individual compounds to form active polymerizations catalysts, and the actual activity of those catalysts, will be dependent on the structure of the individual compound used, and the circumstances under which it is used. For instance, whether such a compound will be active and how active it will be will be dependent to some extent on its actual structure, and particularly how that structure affects the steric and electronic properties of the compound as a ligand on

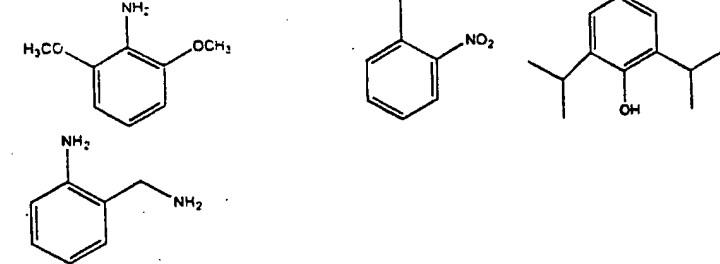
nickel. If there is too much or too little steric hindrance about the group that actually coordinates to the nickel atom, the compound may be ineffective. Similarly, if the group that actually coordinates to the nickel is made too electron rich or poor, the compound may be made ineffective.

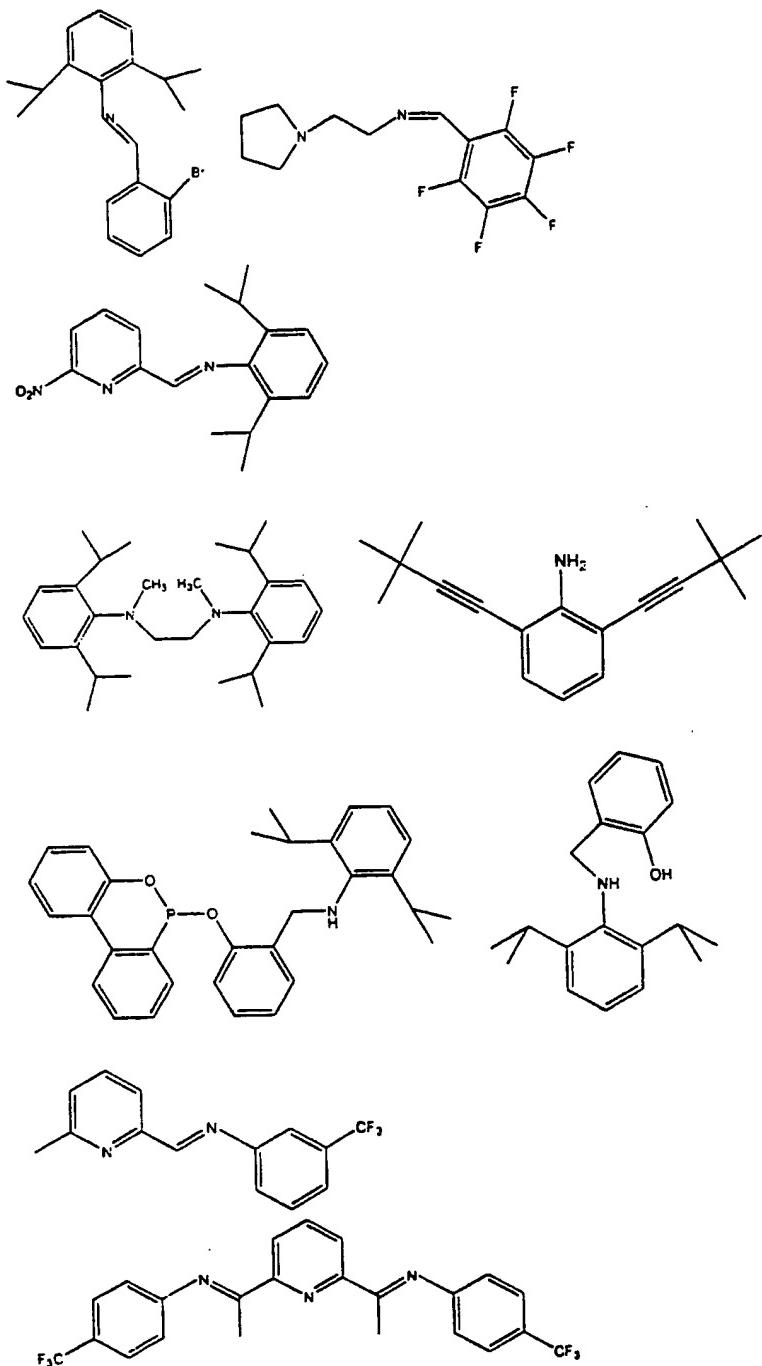
This may be illustrated by the following list of compounds, which were ineffective in catalyzing the polymerization of ethylene under the conditions described for Examples 23-66. The specific compounds are:

10



15





10

However, as mentioned above these compounds failed under a specific set of conditions. If one peruses through the Examples herein, one will find that certain of these compounds may fail to promote polymerization by one method, while be active in another

method, and/or one finds the yield of polymer may change significantly under different conditions. Therefore failure in any particular polymerization process doesn't mean failure in all.

Conditions in such processes may be varied, for instance the pressure, temperature and solvent used. The polymerizations may be carried out in slurry, solution or the gas phase, in continuous, semi-batch or batch reactors. In addition, the particular starting form of the (proto)catalyst system may affect reactivity. For instance, differences may be found when using 10 (II) as a starting material than when using a preformed π -allyl complex.

Determining the activity of any particular compound which is described herein is relatively easy. The compound may be used in any of the polymerization systems described herein, and if needed 15 the conditions, such as temperature and pressure, may be varied. Particularly for polymerizations in which the active nickel catalyst is formed *in situ*, it may be important that the catalyst components all be soluble, at least initially, so solvent selection may be important. Such experiments are simple and quick 20 to run and don't involve much experimentation.

It is also noted that some forms of (XXXXIII) may be prepared by other methods known in the art, see for instance copending U.S. Application Number 08/590,650, filed January 24, 1996 (CR9608D) which is hereby included by reference.

25 In all of the polymerization processes and polymerization catalysts herein it is preferred that one or more of the following not be significantly present: an organoaluminum compound; an aluminum halide; any other transition metals, especially titanium and/or zirconium; reducing agents, especially metal or metalloid hydrides; and any organometallic compound except for nickel 30 compounds. By not significantly present is meant there is not enough present to affect the course of the polymerization. It is more preferred that one or more of these be absent from a polymerization process and/or polymerization catalyst, except for 35 normal impurities. It is also preferred that a polymerization catalyst or catalyst system for a polymerization process herein consist essentially of the stated ingredients.

In all of the nickel complexes herein, except those specifically enumerated as nickel [0] complexes, it is preferred that the nickel be in the +2 oxidation state.

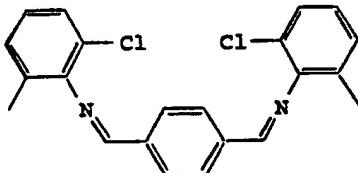
In the Examples the following abbreviations are used:

| | |
|----|--|
| 5 | BAF - {tetrakis[3,5-bis(trifluoromethyl)phenyl]borate} |
| | Bu - butyl |
| | COD - η^4 -1,5-cyclooctadiene |
| | Cy - cyclohexyl |
| | DSC - differential scanning calorimetry |
| 10 | Et - ethyl |
| | Me - methyl |
| | Ph - phenyl ($C_6H_5^-$) |
| | RT - room temperature |
| | Tg - glass transition temperature |
| 15 | THF - tetrahydrofuran |
| | TLC - thin layer chromatography |
| | Tm - melting point |

In the Examples, all ethylene pressures are gauge pressures unless otherwise noted. The formulas given for the nickel complexes of specific ligands in the Examples may not be accurate and are for illustration purposes only. They represent the best estimate of the structure (or one of several possible structures) based on available data.

Example 1

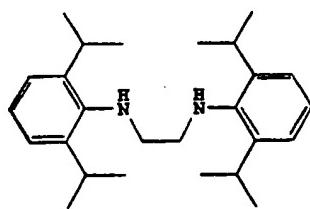
Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (VI) (0.023 g, 0.06 mmol) (purchased from the SALOR fine chemical division of Aldrich Chemical Co.) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was washed with methanol and dried; yield of polymer = 9.1 g. ¹H NMR (CDCl₃/CDCl₂, 120°C) showed that this sample contained 90 methyl-ended branches per 1000 methylenes. Two melting points were observed by differential scanning calorimetry: a very broad melting point centered at approximately 0°C, and a sharp melting point at 115°C.



(VI)

Example 2

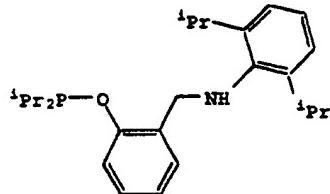
Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (VII) (0.023 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 4.9 g. By ¹H NMR integration it was shown that this material was branched polyethylene containing 109 methyl-ended branches per 1000 methylenes. ¹H NMR (CDCl₃) δ 1.24 (s, methylene and methine protons), 0.82 (d, methyls).



(VII)

Example 3

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (VIII) (0.024 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.26 g. ¹H NMR (C₆D₃Cl₃, 120°C) showed that this sample contained 18 methyl-ended branches per 1000 methylenes.

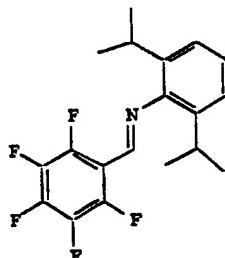


(VIII)

Example 4

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (IX) (0.020 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was washed with methanol and dried; yield of polymer = 0.73 g. T_m = 126.9°C (second heat) as determined by DSC. ¹H NMR (CDCl₂/CDCl₂, 25°C) showed that this

sample contained approximately 7 methyl-ended branches per 1000 methylenes.

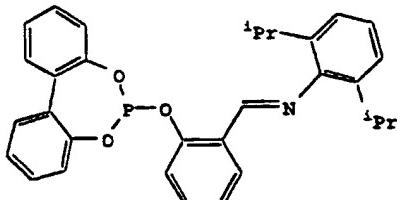


(IX)

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Example 5

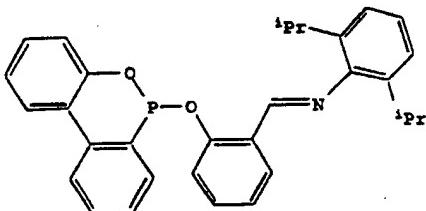
Under a nitrogen atmosphere, $\text{Ni}(\text{COD})_2$ (0.017 g, 0.06 mmol) and compound (X) (0.030 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF'(Et_2O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C_2H_4 for 18 h at 25°C. The final reaction mixture contained polyethylene, which was washed with methanol and dried; yield of polymer = 1.40 g. $T_m = 123.6^\circ\text{C}$ as determined by DSC. ^1H NMR ($\text{CDCl}_2/\text{CDCl}_2$, 120°C) showed that this sample contained approximately 10 methyl-ended branches per 1000 methylenes.



(X)

Example 6

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (XI) (0.029 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF' (Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.43 g. ¹H NMR (CDCl₂/CDCl₂, 120°C) showed that this sample contained 19 methyl-ended branches per 1000 methylenes.



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(XI)

Example 7

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and 2,6-diisopropylaniline (0.011 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF' (Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.72 g. T_m = 121.3°C (second heat) as determined by DSC. ¹H NMR (C₆D₃Cl₃, 120°C) showed that this sample contained 26 methyl-ended branches per 1000 methylenes. Another experiment run under identical conditions afforded 0.17 g of polymer; three other experiments in which 0.12 mmol of 2,6-diisopropylaniline were employed (other conditions the same as above) afforded 0.30 g, 0.20 g, and 0.64 g of polymer.

Example 8

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and 2,6-diethylaniline (0.018 g, 0.12 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 14 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.34 g. T_m = 122.5°C (second heat) as determined by DSC.

Example 9

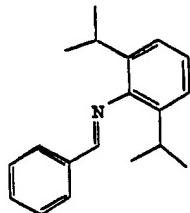
Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and aniline (0.011 g, 0.12 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 14 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.049 g. T_m = 112.0°C as determined by differential scanning calorimetry.

Example 10

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and 1,8-diaminonaphthalene (0.010 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was washed with methanol and dried; yield of polymer = 5.38 g. DSC on this sample showed a very broad melting point, T_m = 37.0°C (second heat).

Example 11

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (XII) (0.016 g, 0.12 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h; during this time the temperature inside the reactor varied between 25 and 33°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.13 g. T_m = 119.3, 129.0°C as determined by DSC.



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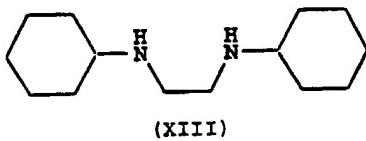
(XII)

Example 12

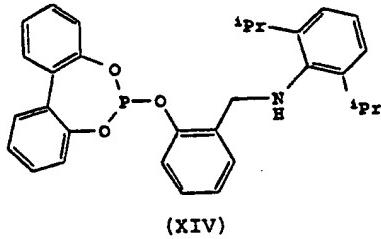
Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and ortho-phenylenediamine (0.013 g, 0.12 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.052 g. T_m = 98.0, 119.0°C as determined by DSC.

Example 13

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (XIII) (0.013 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h at 25°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.76 g.

Example 14

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (XIV) (0.030 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF·(Et₂O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C₂H₄ for 18 h; during this time the temperature inside the reactor varied between 25 and 33°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 0.039 g. T_m = 126.2°C as determined by DSC.

Example 15

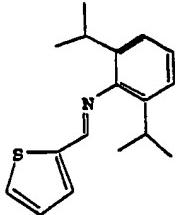
Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and anthranilic acid (0.008 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added

HBAF'(Et_2O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C_2H_4 for 18 h; during this time the temperature inside the reactor varied between 25 and 39°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 1.74 g. T_m = 118.4°C as determined by DSC.

10

Example 16

Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and compound (XXXVIII) (0.008 g, 0.06 mmol) were dissolved in benzene (5.0 mL). To the resulting solution was added HBAF'(Et_2O)₂ (0.060 g, 0.06 mmol). The resulting solution was immediately frozen inside a 40 mL shaker tube glass insert. The glass insert was transferred to a shaker tube, and its contents allowed to thaw under an ethylene atmosphere. The reaction mixture was agitated under 6.9 MPa C_2H_4 for 18 h; during this time the temperature inside the reactor varied between 25 and 34°C. The final reaction mixture contained polyethylene, which was filtered off, washed with methanol and dried; yield of polymer = 1.20 g. T_m = 120.2, 132.3°C as determined by DSC.



(XXXVIII)

25

Example 17Synthesis of (VII)

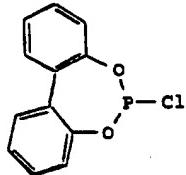
2,6-diisopropylaniline (17.7 g, 100 mmol), 1,2-dibromoethane (9.4 g, 50 mmol), and diisopropylethylamine (20 mL) were heated to reflux for 2 days. Excess diisopropylethylamine was removed from the white crystals in vacuo, and the residue was washed with CH_2Cl_2 . The CH_2Cl_2 was evaporated to give a red-brown residue. The crude product was recrystallized from methanol to afford white crystals of (VII).

Example 18Synthesis of (IX)

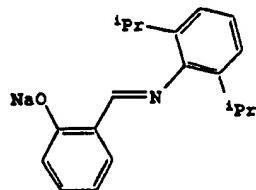
2,6-Diisopropylaniline (0.89 g, 5.0 mmol) and pentafluorobenzaldehyde (0.98 g, 5.0 mmol) were dissolved in CH₂Cl₂ (20 mL) and the reaction mixture was stirred overnight at room temperature. The solvent was removed in vacuo to afford 1.5 g of (IX) as an off-white solid.

Example 19Synthesis of (X)

10 1,1'-Biphenyl-2,2'-diylphosphorochloridite (0.251 g, 1.0 mmol) was dissolved in anhydrous diethyl ether (15 mL) under nitrogen. To this stirred solution was slowly added the sodium salt of salicylaldehyde-2,6-diisopropylanilineimine (0.303 g, 1.0 mmol). The solution was stirred for one hour, and then filtered. 15 The filtrate was evaporated to afford a yellow oil. The oil was redissolved in approximately 3-4 mL petroleum ether. Slow evaporation of the solution at room temperature gave yellow crystals of (X). ¹H NMR (CDCl₃) δ 8.55 (s, 1H, N=CH), 8.25 (d, 1H, Haryl), 7.50-7.05 (mult, 15H, Haryl), 2.95 (sept, 2H, CHMe₂), 1.15 (d, 12H, CHMe₂); ³¹P NMR (CDCl₃) δ 142.44.



1,1'-biphenyl-2,2'-diylphosphorochloridite



25 salicylaldehyde-2,6-diisopropylanilineimine sodium salt

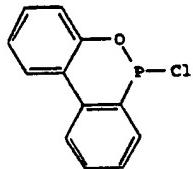
The preparation of 1,1'-biphenyl-2,2'-diylphosphorochloridite can be found in the following references: WO 9303839, U.S. Patents 4,769,498, and 4,688,651, and Cuny, G.D., 30 et al., J. Am. Chem. Soc. vol. 115, p. 2066 (1993).

Salicylaldehyde-2,6-diisopropylanilineimine was prepared by stirring an equimolar mixture of salicylaldehyde and 2,6-diisopropylaniline in the presence of a catalytic amount of formic acid in methanol for several days at room temperature; the product 5 was from pentane at -78°C. The sodium salt was prepared by reaction with sodium hydride in THF.

Example 20

Synthesis of (XI)

Compound (X) I was prepared by the method of Example 19 from 10 6-chloro-6H-dibenz[c,e][1,2]oxaphosphorin and the sodium salt of salicylaldehyde-2,6-diisopropylanilineimine. ^1H NMR (CDCl_3) d 8.20-7.00 (mult, 16H, N=CH and Haryl), 2.80 (sept, 2H, CHMe_2), 1.03 (overlapping d's, CHMe_2 , 12H); ^{31}P NMR (CDCl_3) d 128.8 ppm.



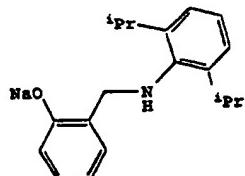
15

6-Chloro-6H-dibenz[c,e][1,2]oxaphosphorin

6-Chloro-6H-dibenz[c,e][1,2]oxaphosphorin was prepared according to a published procedure: Pastor, S.D., et al., *Phosphorus and Sulfur* vol. 31, p. 71 (1987).

Example 21Synthesis of (XIV)

1,1'-biphenyl-2,2'-diylphosphorochloridite (0.125 g, 0.50 mmol) was dissolved in 15 mL 1:1 anhydrous ether/tetrahydrofuran under nitrogen. To this stirred solution was added the sodium salt of N-(ortho-hydroxy)benzyl-2,6-diisopropylaniline (0.153 g, 0.50 mmol). Stirring was continued for another 5.5 hours before the solution was filtered. Evaporation of the filtrate afforded a nearly colorless oil. This material was redissolved in diethyl ether/petroleum ether (-1:2), and the solution cooled to -40°C. A small amount of material precipitated from the solution and was removed. Slow evaporation of the solution afforded white crystals of compound XIV. ^1H NMR (CDCl_3) δ 7.60-7.00 (mult, 15H, Haryl), 4.05 (s, 2H, CH_2), 3.40 ppm (br s, 1H, NH), 3.25 (sept, 2H, CHMe_2); 1.10 (d, 12H, CHMe_2).

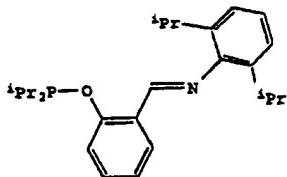


N-(ortho-hydroxy)benzyl-2,6-diisopropylaniline sodium salt

N-(ortho-hydroxy)benzyl-2,6-diisopropylaniline was prepared by NaBH_4 reduction of salicylaldehyde-2,6-diisopropylanilineimine in $\text{CH}_3\text{OH}/\text{CHCl}_3$ (chloroform was added to help solubilize the aniline starting material). The sodium salt of this compound was prepared by reaction with sodium hydroxide in tetrahydrofuran.

Example 22Synthesis of (VIII)

Compound (VIII) was prepared by reduction of N-(ortho-diisopropylphosphinoxy)benzyl-2,6-diisopropylanilineimine with 2 equivalents of $i\text{-Bu}_2\text{AlH}$ in toluene at 0°C, followed by warming to room temperature and a basic workup.



N- (ortho-diisopropylphosphinoxy)benzyl-2,6-diisopropylanilineimine

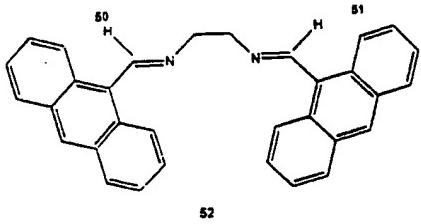
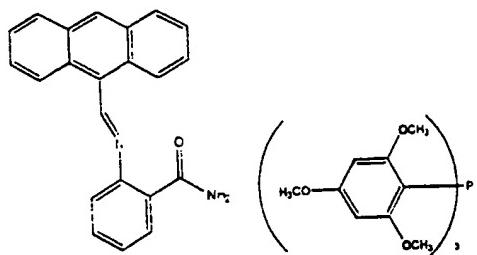
5 N- (ortho-diisopropylphosphinoxy)benzyl-2,6-
diisopropylanilineimine was prepared by reaction of
salicylaldehyde-2,6-diisopropylanilineimine with
chlorodiisopropylphosphine and triethylamine in toluene at room
temperature.

Examples 23-66

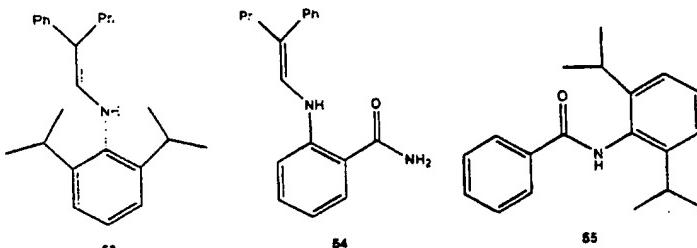
10 These Examples were all done by the same general procedure.
Under a nitrogen atmosphere, Ni(COD)₂ (0.017 g, 0.06 mmol) and the
ligand to be tested (0.06 or 0.12 mmol) were dissolved in benzene
(5.0 mL). To the resulting solution was added HBAF' (Et₂O)₂ (0.060
g, 0.06 mmol). The resulting solution inside a 40 mL shaker tube
15 glass insert was immediately frozen in a freezer inside the glove
box. The glass insert was transferred to a shaker tube, and its
contents allowed to thaw under an ethylene atmosphere of 6.9 MPa.
The reaction mixture was agitated under 6.9 MPa of ethylene
pressure for about 18 h. Any polyethylene in the final reaction
20 mixture was washed with methanol and dried. Melting points of
some of the polymers were determined by DSC. These (when
determined) along with polymer yields and other data are given in
Table 1. The structures of the ligands (except if already shown
above) are listed after Table 1.

Table 1

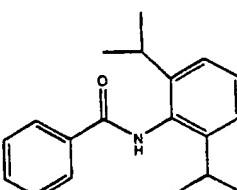
| Ex. | Ligan | Ligand/ | g PE | Tm. °C |
|-----|--------|---------|------|--------|
| 23 | 50 | 1.0 | 24.4 | 123 |
| 24 | 51 | 2.0 | 15.5 | 139 |
| 25 | 52 | 1.0 | 11.0 | - |
| 26 | 53 | 2.0 | 10.2 | 124 |
| 27 | 54 | 1.0 | 5.3 | 124 |
| 28 | 55 | 2.0 | 4.6 | 125 |
| 29 | 56 | 1.0 | 4.3 | - |
| 30 | 57 | 1.0 | 4.0 | 136 |
| 31 | 58 | 1.0 | 3.9 | 118 |
| 32 | 59 | 1.0 | 3.6 | - |
| 33 | 60 | 1.0 | 3.1 | 112 |
| 34 | 61 | 1.0 | 3.0 | 124 |
| 35 | 62 | 1.0 | 3.0 | 123 |
| 36 | 63 | 1.0 | 2.9 | 128 |
| 37 | 64 | 2.0 | 2.6 | - |
| 38 | 65 | 1.0 | 2.1 | - |
| 39 | 66 | 1.0 | 1.8 | 131 |
| 40 | 67 | 1.0 | 1.7 | 118 |
| 41 | 68 | 1.0 | 1.6 | 123 |
| 42 | 69 | 1.0 | 1.5 | - |
| 43 | 70 | 1.0 | 1.5 | - |
| 44 | (XIX) | 1.0 | 1.4 | 121 |
| 45 | 71 | 1.0 | 1.3 | - |
| 46 | (XXXV) | 1.0 | 1.2 | 126 |
| 47 | 72 | 1.0 | 1.1 | 131 |
| 48 | 73 | 1.0 | 1.0 | - |
| 49 | 74 | 1.0 | 1.0 | 117 |
| 50 | 75 | 1.0 | 9 | - |
| 51 | 76 | 1.0 | 9 | - |
| 52 | 77 | 1.0 | 9 | 124 |
| 53 | 78 | 1.0 | 8 | - |
| 54 | 79 | 2.0 | 8 | - |
| 55 | 80 | 2.0 | 7 | - |
| 56 | 81 | 1.0 | 7 | 127 |
| 57 | 82 | 1.0 | 7 | 65 |
| 58 | 83 | 2.0 | 6 | - |
| 59 | (XVII) | 1.0 | 6 | - |
| 60 | 84 | 1.0 | 6 | - |
| 61 | 85 | 2.0 | 6 | - |
| 62 | 86 | 2.0 | 5 | - |
| 63 | 87 | 1.0 | 5 | - |
| 64 | 88 | 1.0 | 5 | - |
| 65 | 89 | 2.0 | 5 | - |
| 66 | 90 | 1.0 | 4 | - |



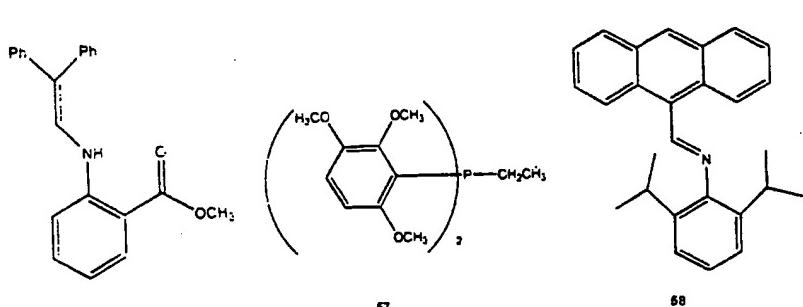
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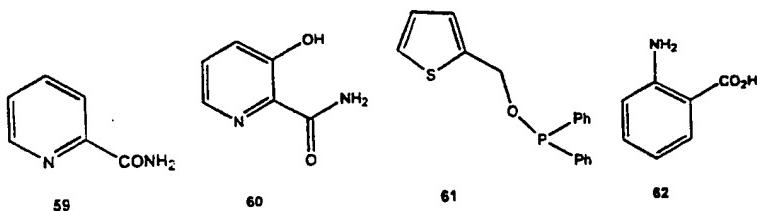
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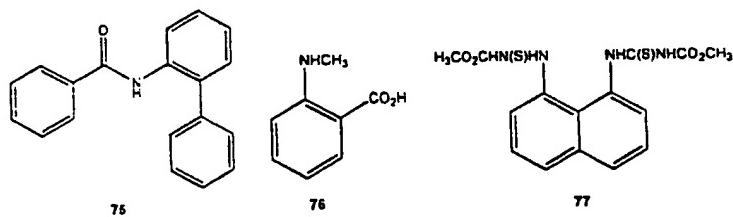
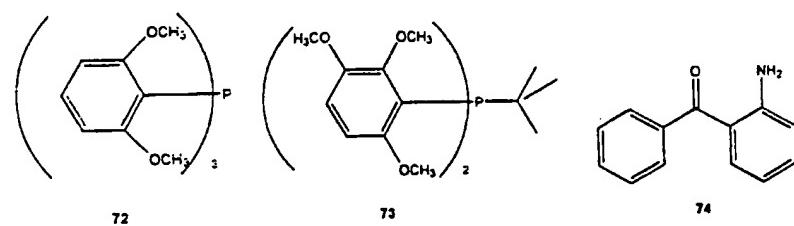
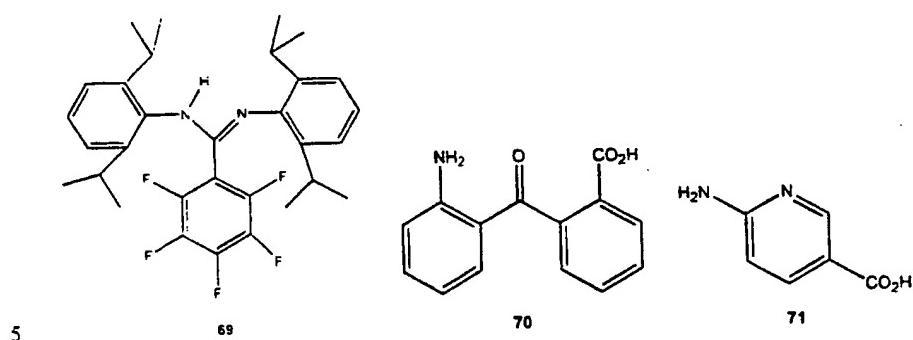
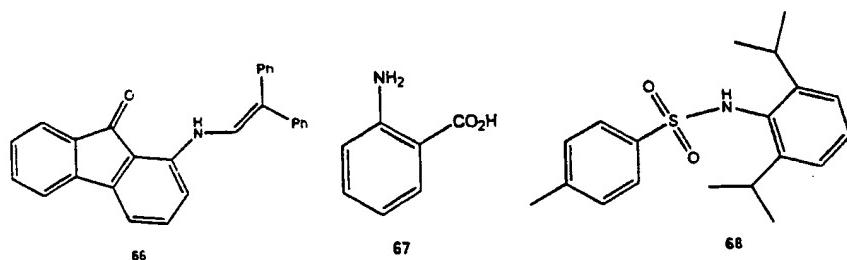
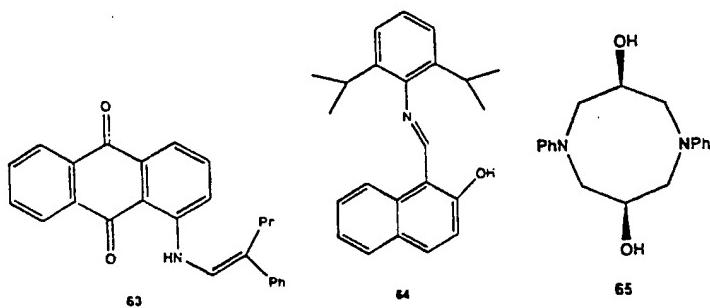


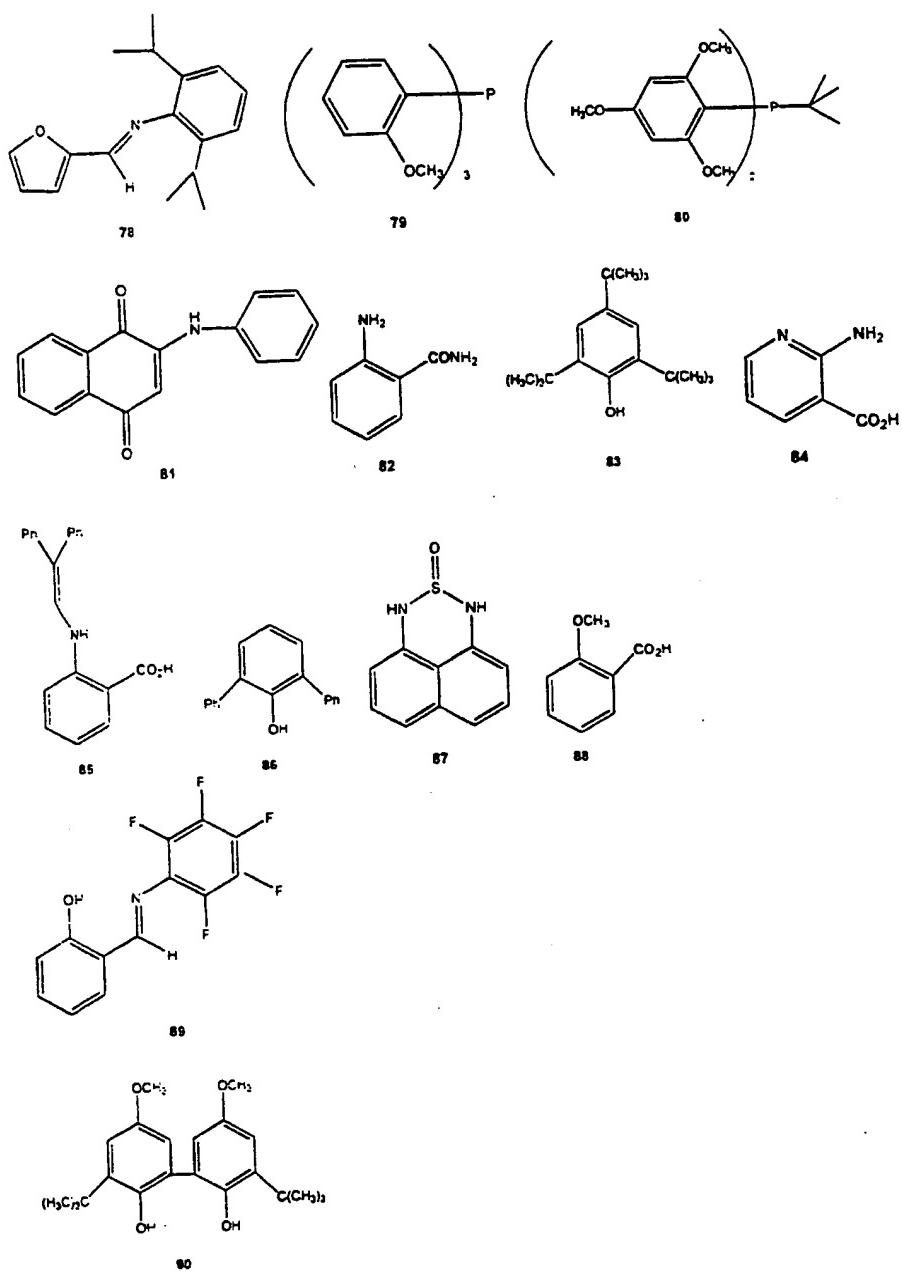
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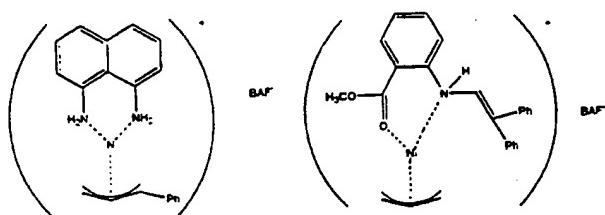
Examples 67-77Norbornene Polymerization

General procedure: The reactions were carried out in a dry, deoxygenated atmosphere. The catalyst was weighed into a 20 ml glass scintillation vial and a stir bar was added. A solution of dry dichloromethane/norbornene (3 ml, 43 mass % norbornene) was added and the resulting solutions stirred for 20-90 h. Each product was added to stirring methanol (in air) to precipitate the polymer. The polymer was filtered, washed with methanol/10% HCl solution and methanol and finally dried under vacuum. In each case purity was improved by redissolving the polymer in chloroform and reprecipitating with methanol. $^1\text{H-NMR}$ (CDCl_3) confirmed that the products were addition polymers of norbornene. Details and results of these polymerization are given in Table 2. Structures of the catalysts used are shown after Table 2

Table 2

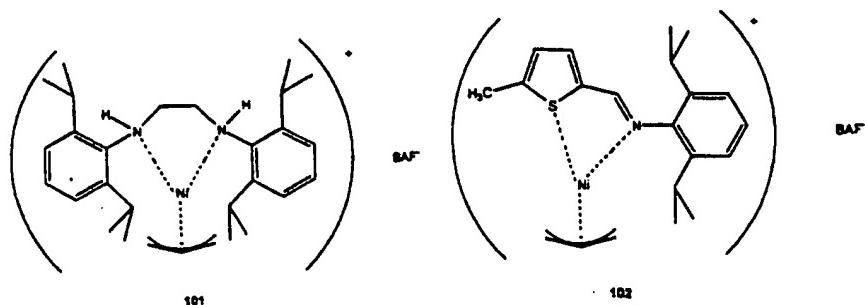
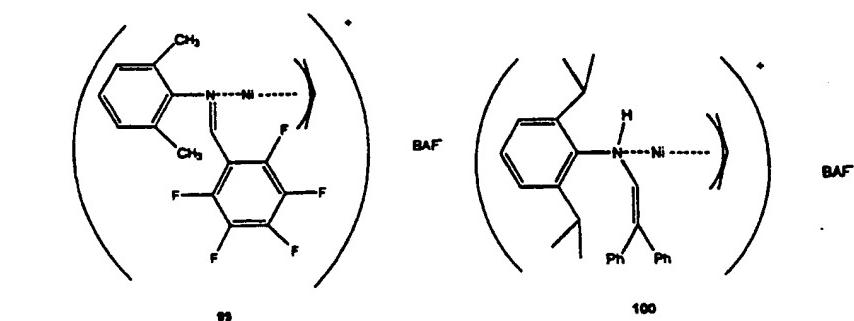
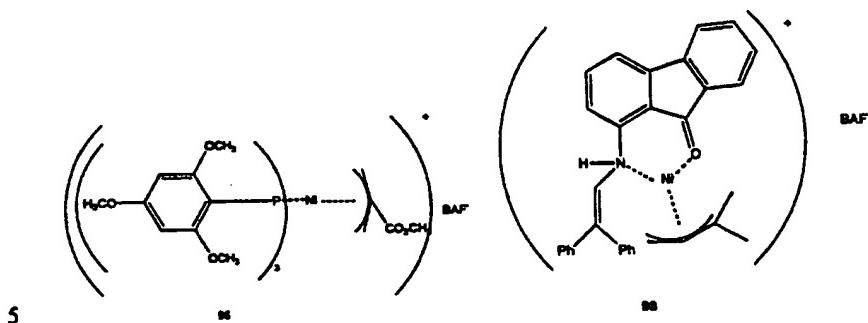
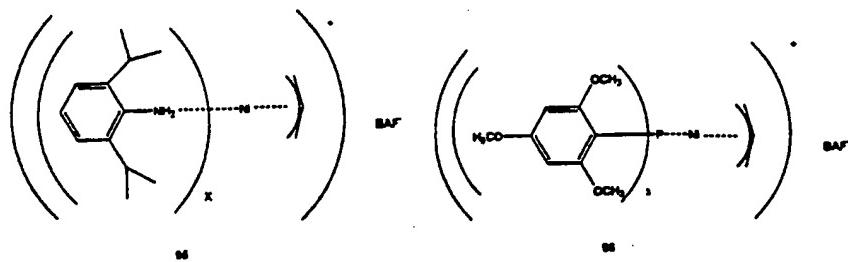
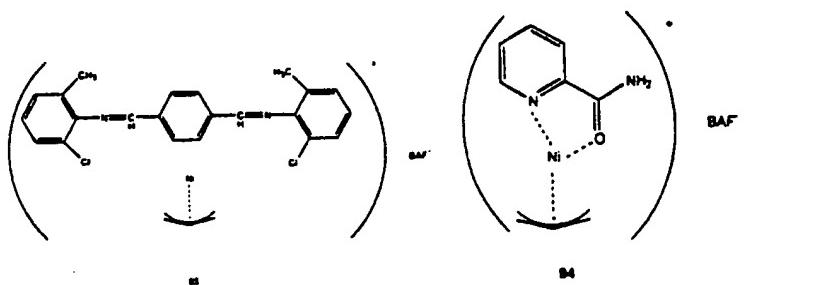
| Ex. No. | Catalyst | mmol | Time, h | % Yield | Comments |
|------------|-----------------|-------|------------|------------|--|
| 67 | 91 | 0.050 | 20 | >95% | Solution was solidified within 5 min. |
| 68 | 92 | 0.041 | 20 | >95% | Solidified over several h |
| 69 | 93 ^a | 0.030 | 20 | 93% | Exothermic, boiled solvent |
| 70 | 94 | 0.016 | 44 | 45% | Viscosity increased over several days |
| 71 | 95 ^a | 0.036 | 20 | >95% | Exothermic, solidified within 1 min |
| 72 | 96 | 0.010 | 20 | 94% | Solidified over 1 h |
| 73 | 98 | 0.039 | 20 | 85% | No stirring after 20 min (too viscous) |
| 74 | 99 | 0.019 | 20 | 88% | Exothermic, solid within 10 sec |
| 75 | 100 | 0.020 | 20 | 81% | Exothermic, solid within 5 sec |
| 76 | 101 | 0.041 | 20 | >95% | Solidified overnight |
| 77 | 102 | 0.018 | 20 | 87% | Exothermic, solidified rapidly |

^a End groups visible in ¹H NMR of polymer indicate lower molecular weight



91

92



Examples 78-85Styrene Polymerization

General procedure: The reactions were carried out in a dry, deoxygenated atmosphere. The nickel containing catalyst was weighed into a 20 ml glass scintillation vial and a stir bar added. Dry dichloromethane (2 ml) followed by styrene (2 ml, filtered through alumina, phenothiazine inhibitor) was added and the resulting solutions shaken in the dark for 20 h. The products were added to stirring methanol (in air) to precipitate the polymer. The polymer was filtered, washed with methanol/10% HCl solution and methanol and finally dried under vacuum. Polymers were characterized using ^{13}C -NMR (CDCl_3) which indicated that in each case the product was enriched in racemic diad units relative to atactic polystyrene [for measuring tacticities of polystyrenes see T. Kawamura, et al., *Macromol. Rapid Commun.*, vol. 15, p. 479-486 (1994)]. Details of each polymerization and results are shown in Table 3. Structures of catalysts are shown after Table 2, above.

Table 3

20

| Ex. No. | Catalyst | mmol | % Yield | Comments |
|------------|----------|-------|------------|---|
| 78 | 91 | 0.017 | 37% | Golden solution |
| 79 | 92 | 0.016 | >95% | Brown viscous solution |
| 80 | 93 | 0.015 | 80% | Rapid reaction, viscous brown solution |
| 81 | 95 | 0.017 | 71% | Rapid, orange solution turns brown, viscous |
| 82 | 96 | 0.006 | 6% | Golden solution |
| 83 | 98 | 0.016 | 84% | Boils solvent, dark red viscous solution |
| 84 | 101 | 0.016 | 5% | Yellow solution |
| 85 | 102 | 0.027 | 73% | Yellow solution, rapidly became viscous |

Examples 86-94Styrene/Norbornene Copolymerization

General procedure: The reactions were carried out in a dry, deoxygenated atmosphere. The catalyst was weighed into a 20 ml glass scintillation vial and dry dichloromethane (1 ml) and a stir bar added. A solution of dry dichloromethane (2 ml), styrene (2 ml, Aldrich Chemical Co., 99+%, filtered through alumina, phenothiazine inhibitor added) and 1.5 g norbornene (Aldrich Chemical Co., 99%) was added and the resulting solutions shaken in the dark for 20 h. The products were added to stirring methanol (in air) to precipitate the polymer. The polymer was filtered, washed with methanol/10% HCl solution and methanol and finally dried under vacuum.

¹H-NMR (CDCl₃) indicated that in each case the product contained both styrene and norbornene. The absence of a resonance between 6.2 and 6.7 ppm (assigned to the ortho protons in chains of polystyrene) confirms that the product is a copolymer [see for instance A. Benaboura, et al., C.R. Acad. Sc. Paris, Ser. 2, vol. 301, p. 229 (1985)]. The absence of a polystyrene Tg in the DSC confirmed that the products are copolymers.

Details and results of these polymerization are found in Table 4. Structures of the nickel containing catalysts are shown after Table 2, above.

Table 4

| Ex No | Catalyst | mmol catalyst | Polymer Yield (g) | Mol % styrene | Comments |
|-------|----------|---------------|-------------------|---------------|---|
| 86 | 91 | 0.019 | 0.72g | <5% | Golden solution, sticky polymer |
| 87 | 92 | 0.015 | 1.49g | 11.1% | Brown solution, polymer precipitated |
| 88 | 93 | 0.012 | 2.47g | 13.7% | Exothermic, precipitated after 5 min |
| 89 | 95 | 0.019 | 2.62g | 50.8% | Orange solution turned red, precipitated |
| 90 | 97 | 0.013 | 0.28g | <5% | Brown solution, small amount polymer |
| 91 | 98 | 0.019 | 2.93g | 41.4% | Red solution, exothermic, precipitated |
| 92 | 99 | 0.009 | 2.64g | 58.1% | Exothermic, golden solution, precipitated |
| 93 | 100 | 0.015 | 2.15g | 24.2% | Gold solution, exothermic, precipitated |
| 94 | 101 | 0.023 | 1.54g | 5.2% | Yellow solution, polymer precipitated |

Examples 95 - 107

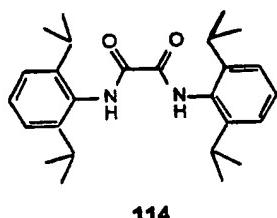
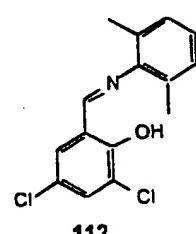
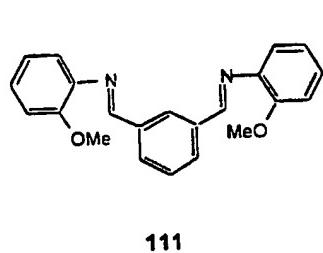
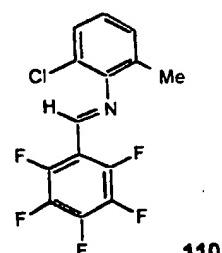
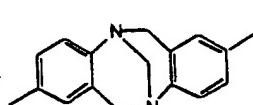
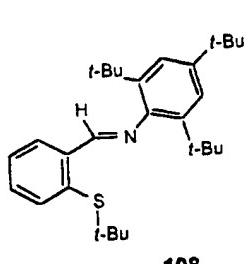
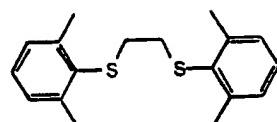
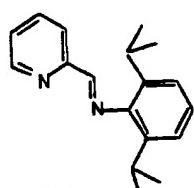
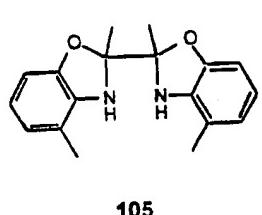
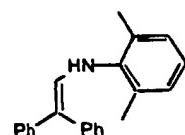
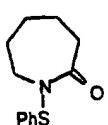
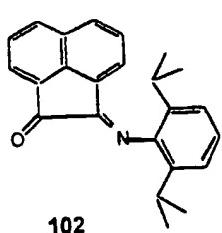
Following the procedure of Examples 23 - 66, ethylene was polymerized. The results are reported in Table 5. The structures of the ligands are listed after Table 5.

5

Table 5

| Ex. No. | Ligand | Ligand/Ni | g PE |
|---------|--------|-----------|------|
| 95 | 102 | 1.0 | 13.8 |
| 96 | 103 | 1.0 | 11.6 |
| 97 | 104 | 1.0 | 10.8 |
| 98 | 105 | 1.0 | 4.3 |
| 99 | 106 | 1.0 | 1.8 |
| 100 | 107 | 1.0 | 1.5 |
| 101 | 108 | 1.0 | 1.4 |
| 102 | 109 | 1.0 | 1.2 |
| 103 | 110 | 1.0 | 0.9 |
| 104 | 111 | 1.0 | 0.6 |
| 105 | 112 | 1.0 | 0.4 |
| 106 | 113 | 1.0 | 0.4 |
| 107 | 114 | 1.0 | 0.2 |

10

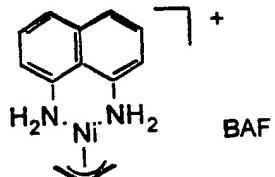


Examples 108-183

General Synthesis of Nickel Allyl Initiators. A mixture of one to two equiv. of the appropriate ligand, one equiv of NaBAF, and 0.5 equiv of $[(\text{allyl})\text{Ni}(\text{m-X})]_2$ ($\text{X} = \text{Cl}$ or Br) was dissolved in Et_2C . The reaction mixture was stirred for several h before being filtered. The solvent was removed in vacuo to yield the desired product. (The $[(\text{allyl})\text{Ni}(\text{m-X})]_2$ precursors were synthesized according to the procedures published in the following reference: Wilke, G., et al., Angew. Chem. Int. Ed. Engl. 1996, 5, 151 - 164.) The following ^1H and ^{13}C spectroscopic assignments of the BAF counterion in CD_2Cl_2 were invariant for different complexes and temperatures and are not repeated in the spectroscopic data for each of the cationic allyl complexes: $[3,5-\text{C}_6\text{H}_3-(\text{CF}_3)_2]_4^+$ (BAF). ^1H NMR (CD_2Cl_2) d 7.74 (s, 8, H_o), 7.57 (s, 4, H_p); ^{13}C NMR (CD_2Cl_2) d 162.2 (q, $J_{\text{CB}} = 37.4$, Cipso), 135.2 (C_O), 129.3 (q, $J_{\text{CF}} = 31.3$, C_m), 125.0 (q, $J_{\text{CF}} = 272.5$, CF₃), 117.9 (C_p).

General Procedure for the Screening of Ethylene

Polymerization by Nickel Allyl Initiators. In the drybox, a glass insert was loaded with the isolated allyl initiator synthesized by the above general procedure. The insert was cooled to -35°C in the drybox freezer, 5 mL of solvent (typically C₆D₆ or CDCl₃) was added to the cold insert, and the insert was then capped and sealed. Outside of the drybox, the cold tube was placed under 6.9 MPa of ethylene and allowed to warm to RT as it was shaken mechanically for approximately 18 h. An aliquot of the solution was used to acquire a ^1H NMR spectrum. The remaining portion was added to ~ 20 mL of MeOH in order to precipitate the polymer. The polyethylene was isolated and dried under vacuum.

Example 108

30

The general synthesis of nickel allyl initiators was followed using 64 mg of ligand, 53 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 347 mg of NaBAF. A wheat yellow powder (307 mg) was isolated. ^1H and ^{13}C NMR spectra are consistent with the above structure with

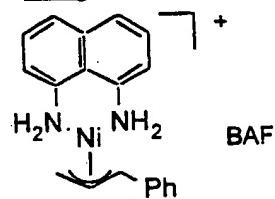
one equiv of Et₂O present. In particular, at -80°C two sets of amino proton resonances are observed and are coupled to each other. This is consistent with the above structure in which both nitrogen atoms are bound to nickel. At room temperature (20°C), one broad resonance is observed at 5.64 ppm for all of the amino protons: ¹H NMR (CD₂Cl₂, 300 MHz, -80°C) d 7.81 (d, 2, J = 8.09, H_O or H_P), 7.41 (t, 2, J = 8.1, H_m), 7.26 (d, 2, J = 6.74, H_O or H_P), 5.49 (m, 1, J = 6.7, H₂CCHCH₂), 5.43 (d, 2, J = 10.8, NHH'), 5.04 (d, 2, J = 12.14, NHH'), 3.38 (br q, 4, J = 6.7, O(CH₂CH₃)₂), 3.26 (d, 2, J = 6.8 (HH'CCHCHH')), 2.17 (d, 2, J = 13.5, HH'CCHCHH')), 0.92 (t, 6, J = 6.1, O(CH₂CH₃)₂); ¹³C NMR (CD₂Cl₂, 75 MHz, rt) d 136.1, 130.4, 129.0, 126.7, 123.2 and 121.7 (Caryl), 115.4 (H₂CCHCH₂), 65.9 (H₂CCHCH₂), 55.7 (O(CH₂CH₃)₂), 14.9 (O(CH₂CH₃)₂).

15

Example 108

The allyl initiator of Example 108 was used to polymerize ethylene in CDCl₃ at RT according to the general polymerization procedure using 24 mg of catalyst. Polyethylene was isolated (304 mg).

20

Example 110

The general synthesis of nickel allyl initiators was followed using 151 mg of ligand, 205 mg of [(H₂CCHCHPh)Ni(μ-Cl)]₂, and 860 mg of NaBAF. A yellow-brown powder (694 mg) was isolated.

25 The ¹H NMR spectrum indicates that one equiv of Et₂O is present. The spectrum, particularly the observation of 4 inequivalent coupled amino protons, is consistent with the above structure in which both nitrogen atoms are bound to nickel. The amino resonances remain inequivalent at least up to 60°C: ¹H NMR (CD₂Cl₂, 300 MHz, -40°C) d 7.85 - 7.25 (m, 10, Haryl), 6.47 (d, 1, J = 6.8, Haryl), 6.03 (t of d, 1, J = 12.8, 7.2, H₂CHCHPh), 5.17 (d, 1, J = 10.8, NHH'), 4.89 (d, 1, J = 10.8, NHH'), 4.23 (d, 1, J = 12.1, N'HH'), 3.73 (d, 1, J = 12.1, H₂CHCHPh), 3.66 (d, 1, J = 10.8, N'HH'), 3.41 (q, 4, J = 7.2, O(CH₂CH₃)₂), 3.34 (d, 1, J =

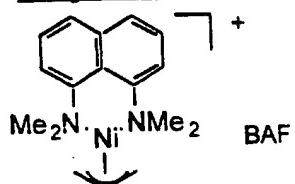
6.8, $\text{HH}'\text{CHCHPh}$), 2.31 (d, 1, $J = 12.1$, $\text{HH}'\text{CCHCHPh}$), 1.05 (t, 6, $J = 7.4$, $\text{O}(\text{CH}_2\text{CH}_3)_2$).

Example 111

The allyl initiator of Example 1110 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 67 mg of catalyst. No polyethylene was isolated under these conditions. However, the ^1H NMR spectrum of the reaction mixture indicated that butenes and higher olefins were produced in significant amounts.

10

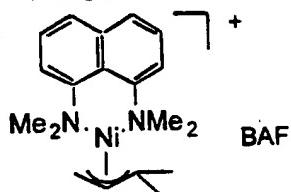
Example 112



The general synthesis of nickel allyl initiators was followed using 202 mg of ligand, 127 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 829 mg of NaBAF. A yellow-orange powder (967 mg) was isolated. The NMR spectra are consistent with the structure shown above, in which both nitrogen atoms coordinate to nickel. ^1H NMR (CD_2Cl_2 , 300 MHz, rt) δ 7.83 (d of d, 2, $J = 5.9, 3.3$, H_m), 7.56 (s, 2, H_o or H_p), 7.54 (d, 2, $J = 2.9$, H_o or H_p), 6.10 (t of t, 1, $J = 13.4$, 7.1 , H_2CCHCH_2), 3.23 (d, 2, $J = 7.3$, $\text{HH}'\text{CCHCHH}'$), 3.1 (br, 12, 2 \times 7.1, H_2CCHCH_2), 2.58 (d, 2, $J = 13.2$, $\text{HH}'\text{CCHCHH}'$); ^{13}C NMR (CD_2Cl_2 , 75 MHz, rt, nonaromatic carbons only) δ 117.6 (H_2CCHCH_2), 60.2 (H_2CCHCH_2), 55.1 (br, NMe_2).

Example 113

The allyl initiator of Example 112 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure (with the exception that 4.1 MPa of ethylene was used) using 40 mg of catalyst. Polyethylene was not isolated. The ^1H NMR spectrum showed the production of butenes and a small amount of higher olefins.

Example 114

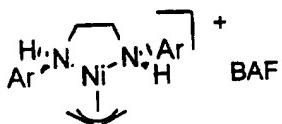
10 The general synthesis of nickel allyl initiators was followed using 103 mg of ligand, 100 mg of $[(\text{H}_2\text{CCHCMe}_2)\text{Ni}(\mu\text{-Br})]_2$, and 427 mg of NaBAF. A pale pink powder (517 mg) was isolated. The NMR spectrum is consistent with the structure shown above, in which both nitrogen atoms coordinate to nickel. ^1H NMR (CD_2Cl_2 , 15 300 MHz, rt) δ 8.2 - 7.4 (m, 6, Haryl), 5.33 (dd, 1, $J = 12.8$, 7.4, $\text{H}_2\text{CCHCMe}_2$), 3.35 - 2.80 (br, 12, NMeMe', N'MeMe'), 2.78 (dd, 1, $J = 8.1$, 2.7, HH'CHCMe₂), 1.75 (dd, 1, $J = 13.5$, 2.7, HH'CHCMe₂), 1.22 and 0.73 (s, 3 each, $\text{H}_2\text{CCHCMeMe}'$).

Example 115

The allyl initiator of Example 114 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 66 mg of catalyst. Polyethylene was isolated (23 mg).

Example 116

The allyl initiator of Example 114 was used to polymerize ethylene in CDCl_3 at 80°C according to the general polymerization procedure using 62 mg of catalyst. No polyethylene was isolated; however, the ^1H NMR spectrum of the reaction mixture showed the production of butenes, higher olefins, and a broad $(\text{CH}_2)_n$ peak at 1.25 ppm.

Example 117

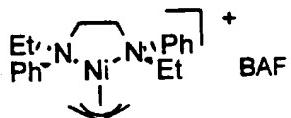
The general synthesis of nickel allyl initiators was followed using 135 mg of ligand, 48 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 307 mg of NaBAF. A yellow powder (394 mg) was isolated. The ^1H and ^{13}C NMR spectra are consistent with both nitrogen atoms coordinating to nickel, as shown above, with the aryl rings lying trans to each other in the majority of the product. Other isomers may be present in lesser amounts: ^1H NMR (CD_2Cl_2 , 300 MHz, -40°C) d 7.4 - 7.0 (m, 6, Haryl), 5.68 (m, 1, H_2CCHCH_2), 5.53, 5.38, 4.84 and 4.22 (m, 1 each, $\text{NCHH}'\text{C}'\text{HH}'\text{N}'$), 3.4 - 2.8 (m, 6, NH, $\text{N}'\text{H}$, CHMe_2 , $\text{C}'\text{HMe}_2$, $\text{C}''\text{HMe}_2$, $\text{C}'''\text{HMe}_2$), 2.73 (d, 1, J = 6.7, CH_2CCH_2 , $\text{C}''\text{CH}_2\text{CCH}_2$), 2.62 (d, 1, J = 6.8, $\text{HH}'\text{CCHCHH}'$), 2.39 (d, 1, J = 13.5, $\text{HH}'\text{CCHCHH}'$), 1.55 (d, 1, J = 13.5, $\text{HH}'\text{CCHCHH}'$), 1.8 - 1.2 (d, 3 each, CHMeMe' , $\text{C}'\text{HMeMe}'$, $\text{C}''\text{HMeMe}'$, $\text{C}''''\text{HMeMe}'$); ^{13}C NMR (CD_2Cl_2 , 75 MHz, rt) d 140.9, 140.8, 139.9, 139.4, 138.9 and 138.4 (Ar: Cipso, Co, Co' and Ar': Cipso, Co, Co'), 129.0, 128.8, 127.1, 127.0, 125.4 and 125.1 (Ar: C_m , C_m' , C_p and Ar': C_m , C_m' , C_p), 116.1 (H_2CCHCH_2), 60.7, 55.9, 54.3 and 53.0 ($\text{H}_2\text{CCHC}'\text{H}_2$, $\text{NCH}_2\text{C}'\text{H}_2\text{N}'$), 31.7, 30.5, 30.0 and 29.4 (CHMe_2 , $\text{C}'\text{HMe}_2$, $\text{C}''\text{HMe}_2$, $\text{C}''''\text{HMe}_2$), 26.4, 26.0, 24.4, 24.2, 24.2, 24.2, 24.0 and 22.9 (CHMeMe' , $\text{C}'\text{HMeMe}'$, $\text{C}''\text{HMeMe}'$, $\text{C}''''\text{HMeMe}'$).

Example 118

The allyl initiator of Example 117 was used to polymerize ethylene in C₆D₆ at 80°C according to the general polymerization procedure using 63 mg of catalyst. Polyethylene (3.49 g) was isolated. ¹H NMR spectrum of the isolated polymer indicates the formation of branched polyethylene with roughly 100 methyl branches per 1000 carbon atoms.

Example 119

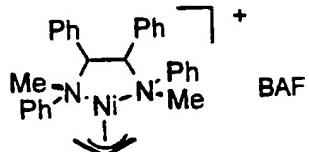
The allyl initiator of Example 117 was used to polymerize ethylene in CDCl₃ at 80°C according to the general polymerization procedure using 68 mg of catalyst. Polyethylene (1.69 g) was isolated.

Example 120

The general synthesis of nickel allyl initiators was followed using 106 mg of ligand, 53 mg of [(C₃H₅)Ni(μ-Cl)]₂, and 349 mg of NaBAF. A yellow powder (394 mg) was isolated. The ¹H and ¹³C NMR spectra are consistent with both nitrogen atoms coordinating to nickel, as shown above, with the aryl rings lying trans to each other in the majority of the product. Other isomers may be present in lesser amounts: ¹H NMR (CD₂Cl₂, 300 MHz, rt) δ 8.3 - 7.2 (m, 10, Haryl), 5.9 (m, 1, H₂CCHCH₂), 3.9 - 2.8 (m, 10, HH'CCHCHH', NCH₂CH₂N', NCH₂CH₃, N'CH₂CH₃), 2.49 (d, 1, J = 13.6, HH'CCHCHH'), 2.15 (d, 1, J = 13.6, HH'CCHCHH'), 1.36 and 1.17 (t, 3 each, J = 7.2, NCH₂CH₃ and N'CH₂CH₃); ¹³C NMR (CD₂Cl₂, 75 MHz, rt) δ 150.1 and 147.5 (Ph: Cipso and Ph': Cipso), 130.8, 130.8, 130.8, 130.7, 129.2, 128.9, 128.2, 124.0, 123.9 and 122.6 (Ph: C_O, C_{O'}, C_m, C_{m'} and C_p; Ph': C_O, C_{O'}, C_m, C_{m'} and C_p), 115.6 (H₂CCHCH₂), 59.6, 58.7, 58.3, 57.9, 57.3 and 56.4 (H₂CCHCH₂, NCH₂CH₃, N'CH₂CH₃, NCH₂CH₂N'), 12.6 and 11.8 (NCH₂CH₃ and N'CH₂CH₃).

Example 121

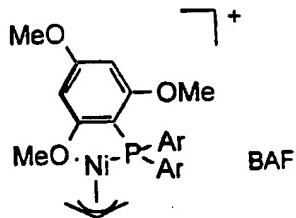
The allyl initiator of Example 120 was used to polymerize ethylene in CDCl_3 at 60°C according to the general polymerization procedure using 25 mg of catalyst. A few mg's of soft white polyethylene was isolated; the ^1H NMR spectrum of this product shows branched polyethylene peaks at 1.25 ppm (CH_2) and 0.85 ppm (CH_3).

Example 122

The general synthesis of nickel allyl initiators was followed using 95 mg of ligand, 34 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 218 mg of NaBAF . A yellow powder (231 mg) was isolated. The ^1H NMR spectrum is complex with more than one isomer apparently present.

Example 123

The allyl initiator of Example 122 was used to polymerize ethylene in CDCl_3 at 60°C according to the general polymerization procedure using 22 mg of catalyst. A few mg's of polyethylene was isolated; the ^1H NMR spectrum of this product shows a $-(\text{CH}_2)-$ peak at 1.2 ppm. The ^1H NMR spectrum of the reaction mixture shows the production of butenes; branched polyethylene peaks are also observable at 1.25 ppm (CH_2) and 0.85 ppm (CH_3).

Example 124

$$\text{Ar} = 2,4,6-\text{C}_6\text{H}_2-(\text{OMe})_3$$

The general synthesis of nickel allyl initiators was followed using 213 mg of ligand, 54 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 354 mg of NaBAF . An orange powder (391 mg) was isolated. Variable-temperature ^1H NMR and ^{13}C NMR spectra are consistent with the above structure in which one methoxy group and the

phosphorus atom are coordinated to nickel. ^1H NMR spectral data are reported at both -100°C and 20°C. Four resonances for the allyl syn and anti protons are observed at -100°C, while two resonances are observed at RT for these protons. The observation of the four syn and anti protons at -100°C supports probable coordination of the methoxy group to nickel: ^1H NMR (CD_2Cl_2 , 300 MHz, -100°C) d 6.05 (d, 6, $J_{\text{HP}} = 4.1$, C_m), 5.59 (m, 1, H₂CCHCH₂), 3.89 (d, 1, J = 6.75, HH'CHC'HH'), 3.76 (s, p-OMe), 3.67 (s, o-OMe), 3.07 (br s, 1, HH'CHC'HH'), 2.93 (dd, 1, J = 13.5, 5.4, HH'CHCHH'), 1.74 (d, 1, J = 12.1, HH'CHCHH'); ^1H NMR (CD_2Cl_2 , 300 MHz, 20°C) d 6.13 (d, 6, $J_{\text{HP}} = 2.7$, C_m), 5.62 (m, 1, H₂CCHCH₂), 3.81 (s, p-OMe), 3.71 (s, o-OMe), 3.49 (d, 2, J = 6.8, HH'CHCHH'), 2.42 (d, 2, J = 16.2, HH'CHCHH'); ^{13}C NMR (CD_2Cl_2 , 75 MHz, rt) d 164.0 (C_p), 162.4 (d, $J_{\text{CP}} = 4.9$, C_O), 113.7 (H₂CCHCH₂), 97.8 (d, $J_{\text{CP}} = 60.4$, Cipso to P), 91.1 (d, J = 4.9, C_m), 57.8 (H₂CCHCH₂ and o-OMe, overlapping), 55.4 (p-OMe).

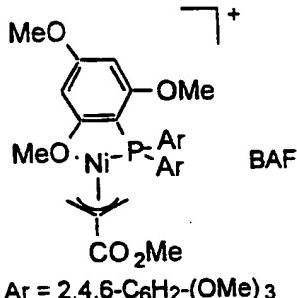
Example 125

The allyl initiator of Example 124 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 28 mg of catalyst. Butenes were formed according to ^1H NMR spectroscopy.

Example 126

The allyl initiator of Example 124 was used to polymerize ethylene in C_6D_6 at RT according to the general polymerization procedure using 28 mg of catalyst. Butenes and some higher olefins were formed according to ^1H NMR spectroscopy.

Example 127



The general synthesis of nickel allyl initiators was followed using 501 mg of ligand, 224 mg of $[(\text{H}_2\text{C}(\text{CO}_2\text{Me})\text{CH}_2)\text{Ni}(\mu-\text{Br})]_2$, and 834 mg of NaBAF. A yellow-green powder (391 mg) was isolated. ^1H NMR spectrum of product is complex; the structure

shown above is tentatively assigned by analogy to the parent (C_3H_5) allyl complex.

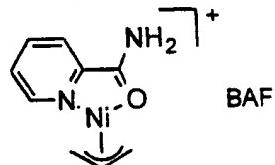
Example 128

The allyl initiator of Example 127 was used to polymerize 5 ethylene in C_6D_6 at RT according to the general polymerization procedure using 93 mg (0.06 mmol) of catalyst and 2 equiv (29 mg) of BPh_3 cocatalyst. Polyethylene (177 mg) was isolated.

Example 129

The allyl initiator of Example 127 was used to polymerize 10 ethylene in $CDCl_3$ at RT according to the general polymerization procedure using 93 mg (0.06 mmol) of catalyst and 2 equiv (61 mg) of $B(C_6F_5)_3$ cocatalyst. Polyethylene (90 mg) was isolated.

Example 130



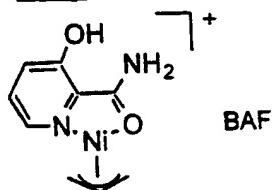
15 The general synthesis of nickel allyl initiators was followed using 45 mg of ligand, 50 mg of $[(C_3H_5)Ni(\mu-Cl)]_2$, and 328 mg of NaBAF. A yellow powder (334 mg) was isolated. The 1H NMR spectral data is consistent with the structure shown above: 20 1H NMR (CD_2Cl_2 , 300 MHz, rt) δ 8.46 (d, 1, $J = 5.4$, Haryl), 8.17 (t, 1, $J = 8.1$, Haryl), 7.84 (d, 1, $J = 8.1$, Haryl), 7.74 (m, 1, Haryl, overlaps with BAF: H_O), 7.10 and 6.82 (br s, 1 each NHH'), 5.99 (m, 1, H_2CCHCH_2), 3.57 (d, 2, $J = 6.8$, $HH'CCHCHH'$), 2.66 (d, 2, $J = 13.5$, $HH'CCHCHH'$). ^{13}C NMR (CD_2Cl_2 , 75 MHz, rt) δ 173.5 ($C=O$), 146.4 (Caryl: $C-C(O)NH_2$), 153.7, 141.4, 131.6 and 123.9 (Caryl attached to hydrogen), 117.2 (H_2CCHCH_2), (H_2CCHCH_2 overlaps 25 with CD_2Cl_2 resonance).

Example 131

The allyl initiator of Example 130 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 63 mg of catalyst. A few mg's of polyethylene was isolated. According to the ^1H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced. Polyethylene - CH_2- resonance is identifiable at 1.25 ppm.

Example 132

10 The allyl initiator of Example 130 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 64 mg of catalyst. Polyethylene (247 mg) was isolated. According to the ^1H NMR spectrum of the reaction mixture, the reaction was productive in the formation of butenes and higher olefins.

Example 133

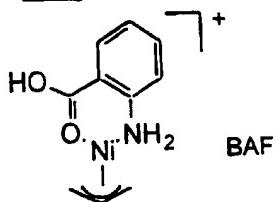
20 The general synthesis of nickel allyl initiators was followed using 52 mg of ligand, 50 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 328 mg of NaBAF. A yellow powder (328 mg) was isolated. The ^1H NMR spectral data is consistent with the structure shown above: ^1H NMR (CD_2Cl_2 , 300 MHz, rt) δ 11.34 (br s, 1, OH), 8.54 (br s, 1, NH $'$), 7.99 (d, 1, $J = 4.0$, Haryl), 7.64 (d, 1, $J = 8.1$, Haryl), 7.55 (t, 1, $J = 4.7$, Haryl), 6.76 (br s, 1, NH $'$), 5.95 (m, 1, HH $'$ CCHCHH $'$), 3.40 (br, HH $'$ CCHCHH $'$, 2.58 (br, HH $'$ CCHCHH $'$). ^{13}C NMR (25 MHz, rt, assignments aided by an APT spectrum) δ 173.7 (CD_2Cl_2 , 75 MHz, rt, assignments aided by an APT spectrum) δ 173.7 (CO), 155.9 and 133.8 (Caryl not attached to hydrogen), 145.8, 132.3 and 129.3 (Caryl attached to hydrogen), 116.6 (H_2CCHCH_2) (H_2CCHCH_2 resonances not observed Neither overlapping with CD_2Cl_2 resonance or broad and in the baseline).

Example 134

The allyl initiator of Example 133 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 60 mg of catalyst. Polyethylene (190 mg) was isolated as a white powder.

Example 135

The allyl initiator of Example 133 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 60 mg of catalyst. Polyethylene (783 mg) was isolated. According to the ^1H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced.

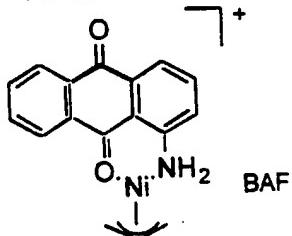
Example 136

The general synthesis of nickel allyl initiators was followed using 57 mg of ligand, 50 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 328 mg of NaBAF. A yellow powder (264 mg) was isolated. The ^1H , ^{13}C , and APT NMR spectral data is consistent with the structure shown above: ^1H NMR (CD_2Cl_2 , 300 MHz, rt) δ 14.0 (br s, 1, OH), 8.10 (d, 1, $J = 8.1$, Haryl), 7.65 (t, 1, $J = 8.1$, Haryl), 7.47 (t, 1, $J = 8.1$, Haryl), 7.21 (d, 1, $J = 8.1$, Haryl), 5.83 (m, 1, H_2CCHCH_2), 4.34 (br s, 2, NH_2), 3.23 (br d, 2, $J = 5.4$, $\text{HH}'\text{CCHCHH}'$), 2.34 (br d, 2, $J = 13.49$, $\text{HH}'\text{CCHCHH}'$).

Example 137

The allyl initiator of Example 136 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 63 mg of catalyst. Polyethylene was not isolated.

5 According to the ^1H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced.

Example 138

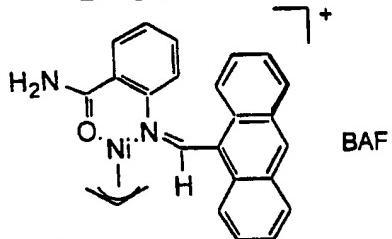
The general synthesis of nickel allyl initiators was followed using 83 mg of ligand, 50 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 10 328 mg of NaBAF. A red powder (381 mg) was isolated. ^1H NMR (CD₂Cl₂, 300 MHz, rt): The complex formed a clear red solution in CD₂Cl₂ with no precipitate present. However, the lock signal and 15 spectrum were both broad, possibly indicating paramagnetism. The above structure is tentatively assigned by analogy to diamagnetic complexes containing ligands with similar donor functionality.

Example 139

The allyl initiator of Example 138 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 63 mg of catalyst. Polyethylene (88 mg) was isolated.

Example 140

The allyl initiator of Example 138 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 60 mg of catalyst. Polyethylene (64 mg) was isolated. According to the ^1H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced.

Example 141

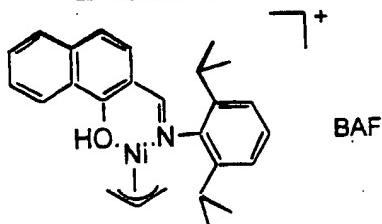
The general synthesis of nickel allyl initiators was followed using 135 mg of ligand, 50 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 328 mg of NaBAF. An orange powder (403 mg) was isolated. The ^1H , ^{13}C , and APT NMR spectral data for the major product follows and is consistent with one isomer of the above structure. Other isomers may be present in lesser amounts: ^1H NMR (CD_2Cl_2 , 300 MHz, rt) d 9.77 and 8.83 (s, 1 each, N=CH and Haryl), 9.0 - 7.5 (m, 8, Haryl), 6.91 and 6.63 (br s, 1 each, NH H'), 4.6 (br s, 1, H_2CCHCH_2), 3.5 - 2.3 (broad resonances in the baseline, HH'CCCHHH'). ^{13}C NMR (CD_2Cl_2 , 75 MHz, rt, assignments aided by an APT spectrum) d 173.7 (N=CH), 172.9 (CO), 147.4, 131.6, 131.0, 126.5 and 124.7 (Caryl not attached to hydrogen), 136.8, 133.7, 130.3, 130.2, 129.5, 129.3, 127.0, 123.3 and 122.7 (Caryl attached to hydrogen), 113.8 (H_2CCHCH_2). (H_2CCHCH_2 resonances were not observed neither overlapping with CD_2Cl_2 resonance or broad and in the baseline).

Example 142

The allyl initiator of Example 141 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 68 mg of catalyst. Polyethylene (1.60 g) was isolated as a wax.

Example 143

The allyl initiator of Example 141 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 60 mg of catalyst. Polyethylene (5.64 g) was isolated as a wax.

Example 144

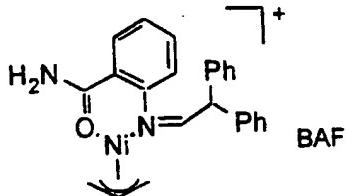
The general synthesis of nickel allyl initiators was followed using 123 mg of ligand, 50 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 15 328 mg of NaBAF. A yellow powder (383 mg) was isolated. The ¹H NMR spectrum is consistent with the above structure, although contamination by free ligand is indicated: ¹H NMR (CD_2Cl_2 , 300 MHz, rt, *i*-Pr and allyl resonances only) δ 5.97 (m, 1, H₂CCHCH₂), 3.76 (br septet and br d, 1 each, CHMe₂ and HH'CHCHH'), 3.53 (br d, 1, J ~ 5.5, HH'CCHCHH'), 3.35 (br septet, 1, C'HMe₂), 2.53 (br d, 1, J = 13.6, HH'CCHCHH'), 2.20 (br d, 1, J = 13.6, HH'CCHCHH'), 20 1.45, 1.43, 1.29 and 1.15 (d, 3 each, J = 6.6 - 7.7; CHMeMe' and C'HMeMe').

Example 145

The allyl initiator of Example 144 was used to polymerize ethylene in CDCl₃ at RT according to the general polymerization procedure using 40 mg of catalyst. Polyethylene (30 mg) was isolated as a white powder. According to the ¹H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced. Minor resonances consistent with the formation of branched polyethylene are present.

Example 146

10 The allyl initiator of Example 144 was used to polymerize ethylene in C₆D₆ at 80°C according to the general polymerization procedure using 64 mg of catalyst. Polyethylene (96 mg) was isolated as a white powder. The ¹H NMR spectrum shows the production of butenes and higher olefins. Polyethylene -CH₂- resonance is identifiable at 1.25 ppm.

Example 147

20 The general synthesis of nickel allyl initiators was followed using 532 mg of ligand, 229 mg of [(C₃H₅)Ni(μ-Cl)]₂, and 1.50 g of NaBAF. 1.85 g of a yellow powder was isolated. Although the free ligand exists as the amine, the ¹H and ¹³C NMR spectra are consistent with the ligand binding to the molecule as the imine: ¹H NMR (THF-d₈, 300 MHz, rt) δ 8.75 (br s, 2, NH₂), 8.55 (d, 1, J = 5.4, N=CH), 7.9 - 7.0 (m, 14, Haryl), 5.56 (d, 1, J = 5.4, CHPh₂), 5.52 (m, 1, H₂CCHCH₂), 3.01 (d, 2, J = 6.7, HH'CCHCHH'), 2.01 (d, 2, J = 13.5, HH'CCHCHH'); ¹³C NMR (THF-d₈, 75 MHz, rt, non-aromatic carbons only, assignments aided by APT spectrum) δ 181.7 (N=CH), 172.8 (C=O), 113.8 (H₂CCHCH₂), 58.7 (CHPh₂), 54.5 (H₂CCHCH₂).

Example 148

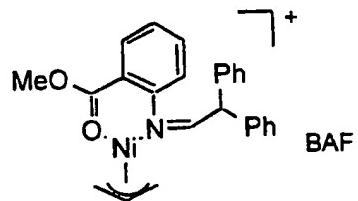
The allyl initiator of Example 147 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 40 mg of catalyst. Polyethylene (25 mg) was isolated as a white powder. According to the ^1H NMR spectrum of the reaction mixture, butenes were formed along with higher olefins; the major product is consistent with branched polyethylene [1.25 (CH_2), 0.85 (CH_3)] with approximately 100 methyl-ended branches per 1000 carbon atoms.

Example 149

10 The allyl initiator of Example 147 was used to polymerize ethylene in C_6D_6 at RT according to the general polymerization procedure using 75 mg of catalyst. Polyethylene (588 mg) was isolated as a white powder.

Example 150

15 The allyl initiator of Example 147 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 61 mg of catalyst. Polyethylene (1.39 g) was isolated. According to the ^1H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced. A significant polyethylene - CH_2- peak appears at 1.25 ppm.

Example 151

25 The general synthesis of nickel allyl initiators was followed using 255 mg of ligand, 105 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu-\text{Cl})]_2$, and 685 mg of NaBAF. 772 mg of a pale green powder was isolated.

Example 152

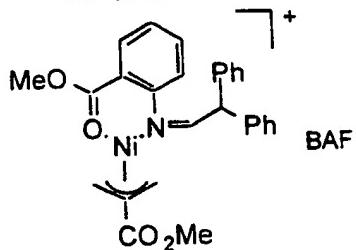
The allyl initiator of Example 151 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 45 mg of catalyst. Polyethylene (1.61 g) was isolated as a white powder.

Example 153

The allyl initiator of Example 151 was used to polymerize ethylene in C_6D_6 at RT according to the general polymerization procedure using 62 mg of catalyst. Polyethylene (93 mg) was isolated as a white powder. The ^1H NMR spectrum shows the production of butenes and higher olefins. Polyethylene - CH_2- resonance is identifiable at 1.25 ppm.

Example 154

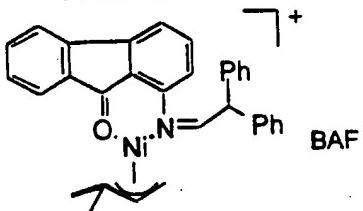
The allyl initiator of Example 151 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 67 mg of catalyst. Polyethylene (169 mg) was isolated. According to the ^1H NMR spectrum of the reaction mixture, the reaction was productive in the formation of butenes and higher olefins. Polyethylene - CH_2- resonance is identifiable at 1.25 ppm.

Example 155

The general synthesis of nickel allyl initiators was followed using 213 mg of ligand, 295 mg of $[(\text{H}_2\text{CC}(\text{CO}_2\text{Me})\text{CH}_2)\text{Ni}(\mu-\text{Br})_2]$, and 795 mg of NaBAF. A gold powder (0.792 g) was isolated.

Example 156

The allyl initiator of Example 155 was used to polymerize ethylene in C₆D₆ at RT according to the general polymerization procedure using 61 mg of catalyst. Polyethylene (1.97 g) was isolated as a white powder.

Example 157

The general synthesis of nickel allyl initiators was followed using 657 mg of ligand, 238 mg of [(H₂CCHCMe₂)Ni(μ-Br)]₂, and 1.56 of NaBAF. A red powder (1.88 g) was isolated. Although the free ligand exists as the amine, the ¹H and ¹³C NMR spectra are consistent with the ligand binding to the molecule as the imine: ¹H NMR (CD₂Cl₂, 300 MHz, rt) δ 8.41 (d, 1, J = 5.4, N=CH), 7.8 - 6.8 (m, 17, Haryl), 5.42 (d, 1, J = 5.4, CHPh₂), 4.80 (dd, 1, J = 12.8, 6.9, H₂CCHCMe₂), 2.95 (d, 1, J = 6.7, HH'CCHCMe₂), 2.03 (d, 1, J = 13.5, HH'CCHCMe₂), 0.77 (s, 6, H₂CCHCMeMe'); ¹³C NMR (CD₂Cl₂, 75 MHz, rt, non-aromatic carbons only, assignments aided by APT spectrum) δ 202.4 (C=O), 182.6 (N=CH), 109.1 (H₂CCHCMe₂), 59.7 (CHPh₂), 53.2 (H₂CCHCMe₂), 43.1 (H₂CCHCMe₂), 26.0 and 20.8 (H₂CCHCMeMe').

Example 158

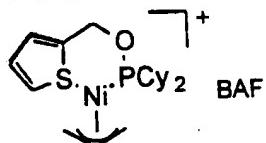
The allyl initiator of Example 157 was used to polymerize ethylene in C₆D₆ at RT according to the general polymerization procedure using 61 mg of catalyst. According to the ¹H NMR spectrum, significant amounts of butenes and higher olefins were produced.

Example 159

The allyl initiator of Example 157 was used to polymerize ethylene in C₆D₆ at 80°C according to the general polymerization procedure using 63 mg of catalyst. According to the ¹H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced

For Examples 160 - 177 where the ligands are thiophene and furan derivatives, the ^1H NMR spectra of the products are, in general, complex and include more than one species. The structural assignments of these complexes are therefore tentative.

5

Example 160

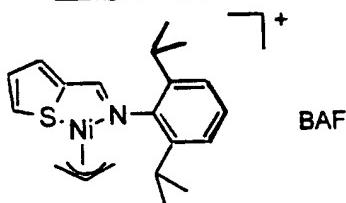
The general synthesis of nickel allyl initiators was followed using 115 mg of ligand, 50 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 328 mg of NaBAF. A sticky dark-red solid (185 mg) was isolated.

10

Example 161

The allyl initiator of Example 160 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure (with the exception that 5.2 MPa of ethylene was used) using 57 mg of catalyst. Polyethylene was not isolated. According to the ^1H NMR spectrum of the reaction mixture, significant amounts of butenes and higher olefins were produced.

15

Example 162

The general synthesis of nickel allyl initiators was followed using 173 mg of ligand, 87 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 570 mg of NaBAF. An orange powder (705 mg) was isolated.

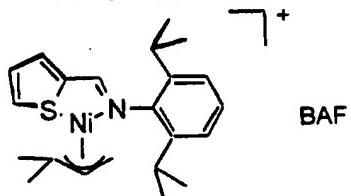
Example 163

The allyl initiator of Example 162 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 64 mg of catalyst. Polyethylene (72 mg) was isolated. The ^1H NMR spectrum of the reaction mixture indicates that significant amounts of butenes and higher olefins were produced.

Example 164

The allyl initiator of Example 162 was used to polymerize 10 ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 68 mg of catalyst. Polyethylene (77 mg) was isolated. The ^1H NMR spectrum of the reaction mixture indicates that significant amounts of butenes and higher olefins were produced.

15

Example 165

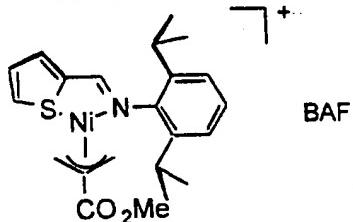
The general synthesis of nickel allyl initiators was followed using 65 mg of ligand, 50 mg of $[(\text{H}_2\text{CCHCMe}_2)\text{Ni}(\mu\text{-Br})]_2$, and 213 mg of NaBAF. An orange powder (163 mg) was isolated.

Example 166

The allyl initiator of Example 165 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 40 mg of catalyst. Polyethylene (823 mg) was isolated as a white powder.

Example 167

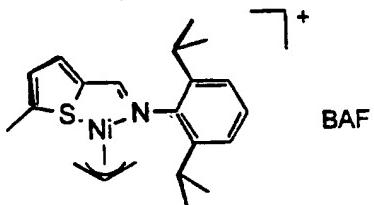
The allyl initiator of Example 165 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 63 mg of catalyst. Polyethylene was not isolated, however, the ^1H NMR spectrum of the reaction mixture indicates significant amounts of butenes and higher olefins were formed.

Example 168

The general synthesis of nickel allyl initiators was followed using 311 mg of ligand, 274 mg of $[(\text{H}_2\text{CC}(\text{CO}_2\text{Me})\text{CH}_2)\text{Ni}(\mu-\text{Br})_2]$, and 1.02 g of NaBAF. An orange powder (1.30 g) was isolated.

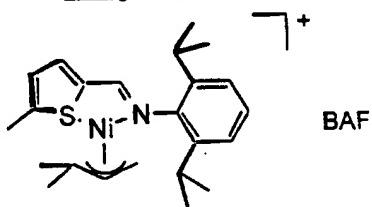
Example 169

The allyl initiator of Example 168 was used to polymerize ethylene in CDCl_3 at 80°C according to the general polymerization procedure using 77 mg of catalyst and 1 equiv (31 mg) of $\text{B}(\text{C}_6\text{F}_5)_3$ cocatalyst. Polyethylene (188 mg) was isolated as a waxy solid. The ^1H NMR spectrum of the reaction mixture indicates that significant amounts of butenes and higher olefins were produced; the polyethylene - CH_2- resonance is identifiable at 1.25 ppm.

Example 170

10

The general synthesis of nickel allyl initiators was followed using 323 mg of ligand, 153 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 1.00 g of NaBAF. An orange powder (1.22 g) was isolated.

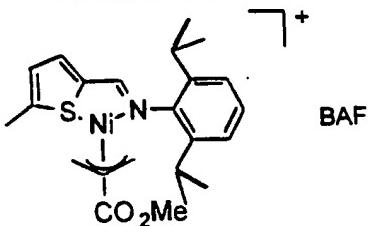
Example 171

15

The general synthesis of nickel allyl initiators was followed using 329 mg of ligand, 239 mg of $[(\text{H}_2\text{CCHMe}_2)\text{Ni}(\mu\text{-Br})]_2$, and 1.02 mg of NaBAF. A sticky red solid (742 mg) was isolated.

Example 172

The allyl initiator of Example 171 was used to polymerize ethylene in C₆D₆ at RT according to the general polymerization procedure using 77 mg of catalyst. Polyethylene (100 mg) was isolated. The ¹H NMR spectrum of the reaction mixture indicates that significant amounts of butenes and higher olefins were produced.

Example 173

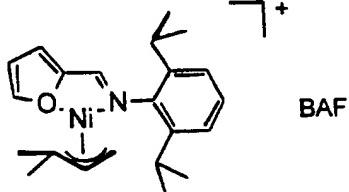
10 The general synthesis of nickel allyl initiators was followed using 327 mg of ligand, 272 mg of [(C₃H₅)Ni(μ-Cl)]₂, and 1.01 g of NaBAF. An orange powder (1.42 g) was isolated.

Example 174

15 The allyl initiator of Example 173 was used to polymerize ethylene in C₆D₆ at RT according to the general polymerization procedure using 78 mg of catalyst and 2 equiv (29 mg) of BPh₃ cocatalyst. Polyethylene was not isolated. The ¹H NMR spectrum of the reaction mixture indicates that significant amounts of butenes and higher olefins were produced.

Example 175

20 The allyl initiator of Example 173 was used to polymerize ethylene in CDCl₃ at 80°C according to the general polymerization procedure using 78 mg of catalyst and 1 equiv (31 mg) of B(C₆F₅)₃ cocatalyst. Polyethylene (2.39 g) was isolated.

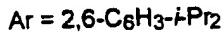
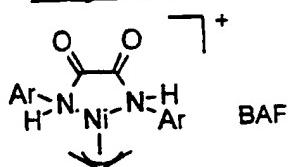
Example 176

25 The above general procedure for nickel allyl initiators was followed using 62 mg of ligand, 50 mg of [(H₂CCHCMe₂)Ni(μ-Br)]₂, and 213 mg of NaBAF. An orange powder (188 mg) was isolated.

Example 177

The allyl initiator of Example 176 was used to polymerize ethylene in CDCl_3 at RT according to the general polymerization procedure using 40 mg of catalyst. No polyethylene was isolated.

5

Example 178

The general synthesis of nickel allyl initiators was followed using 462 mg of ligand, 153 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 1.00 g of NaBAF. A beige powder (1.68 g) was isolated. The stability of the complex is poor in CD_2Cl_2 and THF- d_8 at RT. Only broad NMR spectra were obtained. The above structure is therefore tentatively assigned.

10

Example 179

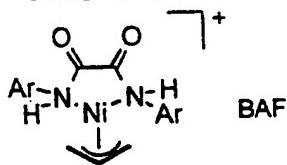
The allyl initiator of Example 178 was used to polymerize ethylene in C_6D_6 at RT according to the general polymerization procedure using 82 mg of catalyst. Polyethylene was not isolated.

15

Example 180

The allyl initiator of Example 178 was used to polymerize ethylene in CDCl_3 at 80°C according to the general polymerization procedure using 82 mg of catalyst. Polyethylene (2.01 g) was isolated.

20

Example 181

The general synthesis of nickel allyl initiators was followed using 462 mg of ligand, 211 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 1.36 mg of NaBAF. A pale orange powder (2.16 g) was isolated. The stability of the complex is poor in CD_2Cl_2 and THF- d_8 at RT. Only broad NMR spectra were obtained. The above structure is therefore tentatively assigned.

25

Example 182

The allyl initiator of Example 181 was used to polymerize ethylene in C₆D₆ at RT according to the general polymerization procedure using 76 mg of catalyst. Polyethylene (147 mg) was isolated.

Example 183

The allyl initiator of Example 181 was used to polymerize ethylene in CDCl₃ at 80°C according to the general polymerization procedure using 76 mg of catalyst. Polyethylene (434 mg) was isolated.

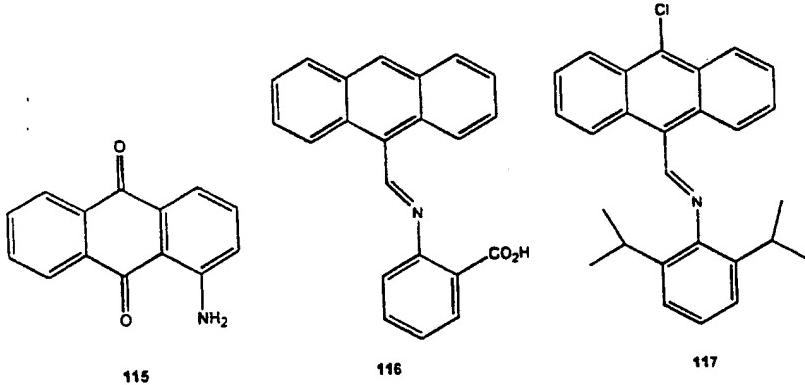
Examples 184 - 177

Following the procedure of Examples 23 - 66, ethylene was polymerized. The results are reported in Table 6. The structures of the ligands are listed after Table 6.

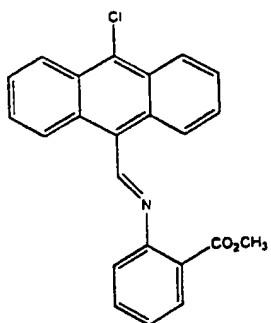
15

Table 6

| Ex. No. | Ligand | Ligand/Ni | g. PE | Tm. °C |
|---------|--------|-----------|-------|--------|
| 184 | 115 | 1 | 9.0 | 125 |
| 185 | 116 | 1 | 2.4 | - |
| 186 | 117 | 2 | 2.7 | - |
| 187 | 118 | 1 | 5.0 | - |



20

Example 188Synthesis of 50

9-Anthrinaldehyde (3.70 g) was dissolved in 100 ml THF in a
 5 200 ml round bottom flask. To the hot solution was added dropwise
 2.77g 2-anthranilamide (in 20 ml THF). Then 4 drops of formic
 acid were added to the mixture. Soon after adding the formic
 acid, yellow precipitate began to form. Heating and stirring were
 continued for another 2 h. After cooling, the solid was isolated
 10 by filtering, followed by washing with methanol and THF to remove
 excess 2-anthranilamide. TLC (5:1 hexane:ethyl acetate) showed a
 single new band. The dried product weighed 3.5g. ¹H NMR (DMSO, δ
 in ppm): 9.82(s, 1H); 8.90(m, 3H); 8.25(m, 3H); 7.90(d, 1); 7.67-7.7(m,
 7H); 7.45(t, 1).

15

Example 189Synthesis of 66

1,1-Diphenylacetaldehyde (0.4906 g) was dissolved in 30 ml
 methanol. To this hot solution was added 0.4881 g
 1-amino-9-fluorenone (in methanol). Then 6 drops of formic acid
 20 was added to catalyze the reaction. Soon after adding the formic
 acid, the color of the solution changed from yellow to orange red,
 then to deep red. At this point, TLC (3:1 hexane:ethyl acetate)
 showed the appearance of new bands. When cooled, a red
 precipitate formed. The precipitate was isolated by filtering
 25 followed by washing with methanol and hexane. The dried product
 weighed 0.4g. The ¹H, ¹³C and APT spectra are consistent with the
 existence of the product as the enamine structure shown above. In
 addition the structure was confirmed by X-ray crystallography. ¹H
 NMR (CD₂Cl₂, 300 MHz, rt) δ 9.25 (d, 1, J = 12.1, NH), 7.6 - 6.85
 30 (m, 18, Haryl and CH=CPh₂); ¹³C NMR (CD₂Cl₂, 75 MHz, rt,

assignments were aided by an APT spectrum) δ 194.0 (C=O), 144.6, 143.1, 142.7, 141.2, 137.7, 134.7 121.3 and 115.15 (Caryl not attached to hydrogen and =CPh₂), 136.6, 133.6, 130.1, 129.2, 128.9, 128.3, 127.6, 126.5, 126.1, 123.1, 121.9, 120.4, 112.7 and 5 110.8 (Caryl attached to hydrogen and =CHN₂Ar).

Example 190

Synthesis of 63

1-Aminoanthraquinone (2.2323 g) was dissolved in a 1:1 mixture of methanol and THF. To the hot solution was added 10 1.9625g 1,1-diphenylacetaldehyde. Then 8 drops of formic acid was added as catalyst. After refluxing for 4 h, heating was removed. TLC (5:1 hexane:ethyl acetate) showed the appearance of a new band which was purple. The solvent was removed by rotary evaporator. The solid was resuspended in ether and stirred. Filtered to 15 collect the solid, followed by washing with a large amount of ether until a single band was obtained. Pure product was also obtained by silica gel chromatography to give a purple solid. Yield 1.2g. ¹H NMR (CD₂Cl₂, δ in ppm): 11.75(d, 1H); 8.20(m, 2H); 7.25-7.85(m, 16H).

20

Example 191

Synthesis of 54

1,1-Diphenylacetaldehyde (3.9250 g) was dissolved in 30 ml anhydrous methanol. To this refluxing solution was added 2.7230 g 2-anthraniilamide (in methanol). Soon a yellow precipitate formed. 25 After all the 2-anthraniilamide was added, heating and stirring were continued for another hour. When cooled, the solid was isolated by filtering. The solid was then resuspended in methanol, stirred and then filtered. Yield 5.1g. The ¹H, ¹³C, and APT spectra are consistent with the existence of the product as the enamine structure shown above: ¹H NMR (THF-*d*₈, 300 MHz, rt, assignments were aided by an APT spectrum) δ 10.86 (br d, 1, J = 12.10, NH-CH=CPh₂), 7.60 - 6.85 (m, 16, Haryl, CH=CPh₂, C(O)NHH'), 6.60 (br s, 1, C(O)NHH'); ¹³C NMR (THF-*d*₈, 75 MHz, rt, assignments were aided by an APT spectrum) δ 171.9 (C=O), 145.9, 30 143.4, 139.7, 120.0 and 116.6 (Caryl not attached to hydrogen and =CPh₂), 113.4, 131.1, 129.4, 128.8, 127.4, 125.9, 124.9, 117.8 and 35 113.4 (Caryl attached to hydrogen and =CHN₂Ar).

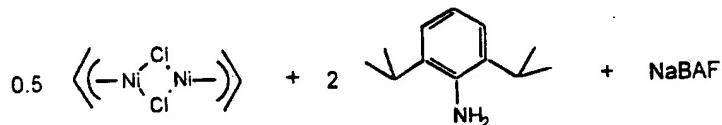
Example 192Synthesis of 56

1,1-Diphenylacetaldehyde (4.0138 g) was dissolved in 20 ml anhydrous methanol. To this hot solution was added 3.0918 g methyl anthranilate (in methanol). The color of the solution changed from colorless to yellow as soon as two components were mixed. After adding all the methyl anthranilate, the heat was turned off. During cooling, a yellow precipitate began to form. The precipitate was collected by filtering followed by washing with methanol. After recrystallization in methanol, 2.6g product was obtained.

10 The ^1H , ^{13}C , and APT spectra are consistent with the existence of the product as the enamine structure shown above. In addition, this structure was confirmed by X-ray crystallography. 15 ^1H NMR (CD_2Cl_2 , 300 MHz, rt) δ 9.94 (br d, 1, $J = 11.73$, NH), 8.05 - 6.75 (m, 15, Haryl and $=\text{CHNHAr}$), 3.78 (s, 3, OMe); ^{13}C NMR (CD₂Cl₂, 75 MHz, rt, assignments were aided by an APT spectrum) δ 168.0 (C=O), 145.4, 141.9, 138.4, 120.9 and 112.1 (Caryl not attached to hydrogen and CH=CPh₂), 134.6, 132.0, 130.3, 129.0, 20 128.4, 127.3, 126.7, 125.9, 123.4, 117.7 and 112.4 (Caryl attached to hydrogen and CH=CPh₂), 51.8 (OMe).

Example 193Synthesis of 58

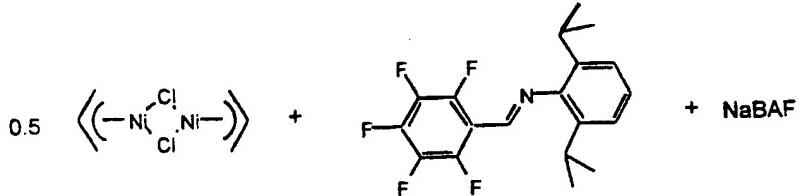
9-Anthraldehyde (2.0624 g) was dissolved in 60 ml of a 1:1 mixture of methanol and THF (the 9-anthralaldehyde did not dissolve completely in methanol). To this refluxing solution was added dropwise 1.7729g 2,6-diisopropylaniline. When the addition was complete, 4 drops of formic acid were added as catalyst. The solution was refluxed for another 2 h before it was cooled. After standing overnight, a yellow solid precipitated. The solid was isolated by filtering followed by washing with methanol. Yield 10 2.5g of dried product. ^1H NMR (CD_2Cl_2 , δ in ppm): 9.51(s, 1H); 9.05(d, 2H); 9.20(s, 1H); 8.20(d, 2H); 7.65(m, 4H); 7.30(d, 2H); 7.25(t, 1H); 3.30(hep, 2H); 1.30(d, 12H).

Example 194

The general synthesis of nickel allyl initiators was followed using 136 mg of ligand, 53 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 342 mg of NaBAF. A yellow powder (430 mg) was isolated.

Example 195.

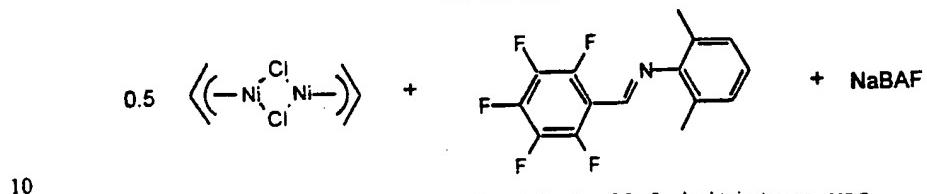
20 The allyl initiator of Example 194 was used to polymerize ethylene in C_6D_6 at 80°C according to the general polymerization procedure using 64 mg of catalyst. Polyethylene (104 mg) was isolated. The ^1H NMR spectrum of the reaction mixture showed that significant amounts of butenes and higher olefins were produced.

Example 196

The general synthesis of nickel allyl initiators was followed using 129 mg of ligand, 51 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 317 mg of NaBAF. A sticky orange solid (217 mg) was isolated.

Example 197

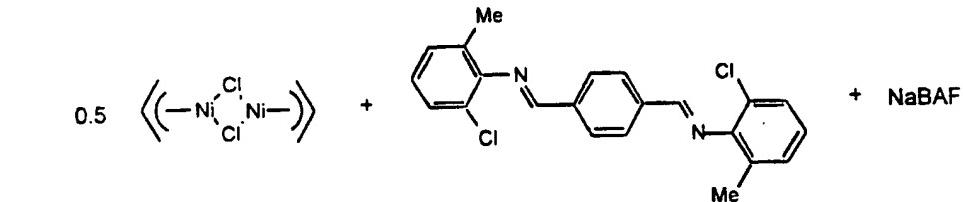
The allyl initiator of Example 196 was used to polymerize ethylene in CDCl_3 at 60°C according to the general polymerization procedure using 24 mg of catalyst. The ethylene pressure was initially 1.2 MPa and was increased to 6.9 MPa after 1 h. A few mg's of polyethylene was produced. The ^1H NMR spectrum of the reaction mixture showed that significant amounts of butenes and higher olefins were produced.

Example 198

The general synthesis of nickel allyl initiators was followed using 136 mg of ligand, 49 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 309 mg of NaBAF. An orange powder (380 mg) was isolated.

Example 199

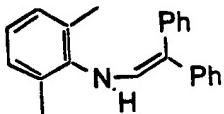
15 The allyl initiator of Example 198 was used to polymerize ethylene in C_6D_6 at RT at 5.2 MPa according to the general polymerization procedure using 63 mg of catalyst. Polyethylene (29 mg) was isolated. The ^1H NMR spectrum of the reaction mixture showed that significant amounts of butenes and higher olefins were produced.

Example 200

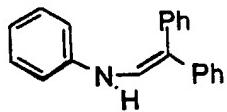
25 The general synthesis of nickel allyl initiators was followed using 111 mg of ligand, 50 mg of $[(\text{C}_3\text{H}_5)\text{Ni}(\mu\text{-Cl})]_2$, and 328 mg of NaBAF. An orange powder (347 mg) was isolated.

Example 202

The allyl initiator of Example 201 was used to polymerize ethylene in CDCl_3 at 60°C according to the general polymerization procedure using 23 mg of catalyst. The ethylene pressure was initially 1.4 MPa and was increased to 6.9 MPa after 1 h. A few mg's of polyethylene was produced. The ^1H NMR spectrum of the reaction mixture showed that significant amounts of butenes and higher olefins were produced.

Example 203

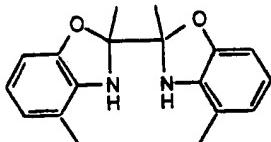
Using 5.47 g of 1,1-diphenylacetaldehyde and 3.60 g of 2,6-dimethylaniline, 5.79 g of an orange powder was obtained following a synthesis analogous to that of the 2,6-diisopropylaniline derivative given above. The ^1H , ^{13}C , and APT spectra are consistent with the existence of the product as the enamine structure shown above: ^1H NMR (CDCl_3 , 300 MHz, rt) δ 7.6 - 7.0 (m, 13, Haryl), 6.88 (d, 1, $J = 12.1$, ArNHCH=CPh₂), 5.47 (d, 1, $J = 12.1$, ArNHCH=CPh₂), 2.37 (s, 6, C₆H₃-Me₂); ^{13}C NMR (CDCl_3 , 75 MHz, rt, assignments aided by an APT spectrum) δ 142.0, 140.7, 138.9 and 131.1 (Ph: Cipso; Ph': Cipso; Ar: Cipso and Co), 131.6, 130.6, 129.3, 128.9, 128.3, 126.9, 125.4, 124.8 and 123.8 (Ph: Co, C_m, Cp; Ph': Co, C_m, Cp; Ar: C_m, Cp; CH=CPh₂), 114.0 (CH=CPh₂), 13.8 (C₆H₃-Me₂).

Example 204

Using 5.43 g of 1,1-diphenylacetaldehyde and 2.71 g of aniline, 5.68 g of yellow powder was obtained following a synthesis analogous to that of the 2,6-diisopropylaniline derivative given above. The ^1H , ^{13}C , and APT spectra are consistent with the existence of the product as the enamine structure shown above: ^1H NMR (CDCl_3 , 300 MHz, rt) δ 7.6 - 6.8 (m, 15, Haryl), 7.18 (d, 1, $J = 12.1$, PhNHCH=CPh₂), 6.12 (d, 1, $J = 11.8$, PhNHCH=CPh₂); ^{13}C NMR (CDCl_3 , 75 MHz, rt, assignments were aided by an APT spectrum) δ 142.7, 141.8 and 138.5 (Ph: Cipso;

Ph': Cipso; Ph'': Cipso), 130.5, 129.6, 129.3, 128.4, 127.2, 126.2, 125.5, 124.8, 120.0 and 113.9 (Ph: Co, Cm, Cp; Ph': Co, Cm, Cp; Ph'': Co, Cm, Cp; CH=CPh₂), 117.7 (CH=CPh₂).

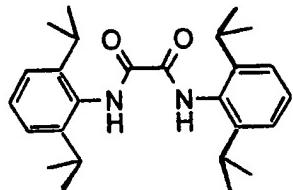
Example 205



5 solution of 1.02 g of 2,3-butanedione in 10 mL of MeOH and 2.92 g of 2-amino-m-cresol were mixed together in a round bottom flask. Formic acid (10 drops) was added via pipette. After ~1.5 h, a precipitate had formed. The solution was stirred overnight 10 and the next day the precipitate was collected on a frit and washed with methanol. The product was then dissolved in Et₂O and stirred overnight over Na₂SO₄. The solution was filtered through a frit with Celite and the solvent was removed in vacuo. A light pink powder was obtained (1.72 g). The ¹H and ¹³C are consistent 15 with the product existing as the cyclized diamine rather than as the diimine. [Note: Literature precedent for this cyclization reaction exists, such as in the reaction of o-aminophenol with glyoxal or the reaction of o-aminobenzoic acid with glyoxal. See: Kliegman, J. M.; Barnes, R. K. *J. Org. Chem.* 1970, 35, 3140 - 3143.]: ¹H NMR (CDCl₃, 300 MHz, rt) δ 6.9 - 6.5 (m, 6, Haryl), 4.58 (s, 2, NH), 2.20 and 1.62 (s, 6 each, Me, Me'); ¹³C NMR (CDCl₃, 75 MHz, rt) δ 141.7, 127.1 and 122.3 (Ar: Cipso, Co, Co'), 122.6, 119.8, 114.9 (Ar: Cm, Cm', Cp), 82.0 (-OC(Me)NH-), 22.1 and 16.7 (Me, Me').

25

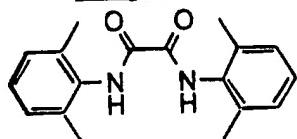
Example 206



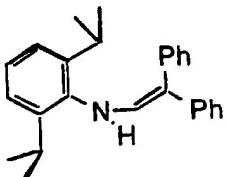
n a nitrogen-filled drybox, 20.01 g of lithium 2,6-diisopropylanilide was placed in a 2-neck round bottom flask and dissolved in 300 mL of Et₂O. A 60 mL solution of 6.93 g of oxalyl 30 chloride was placed in an addition funnel. The oxalyl chloride was added to the reaction mixture over a period of several hours

and the mixture was then stirred overnight. Some of the product precipitate out of the Et₂O solution along with the LiCl. Some of the Et₂O was removed in vacuo and enough THF was added to dissolve the product. The solution was filtered through a frit with 5 Celite, the Celite was washed with THF, and the solvent was removed in vacuo. The product was washed with pentane and pumped dry to give 20.72 g of an off-white powder: ¹H NMR (CDCl₃, 300 MHz, rt) δ 9.26 (br s, 2, NH), 7.23 - 7.04 (m, 6, Haryl), 2.94 (septet, 4, CHMe₂), 1.09 (d, 24, CHMe₂).

10

Example 207

Following the synthetic procedure of the above example, 7.49 g of oxalyl chloride and 15.00 g of lithium 2,6-dimethylanilide was used to synthesize 23.98 g of product, which was isolated as 15 an off-white powder: ¹H NMR (CDCl₃, 300 MHz, rt) δ 9.53 (br 2, 2, NH), 7.00 - 6.86 (m, 6, Haryl), 2.10 (s, 12, Me).

Example 208

Formic acid catalyst (~ 1 mL) was added to a methanol 20 solution of diphenylacetaldehyde (4.44 mL) and 2,6-diisopropylaniline (3.18 mL). After ~ 15 minutes of stirring, a white precipitate formed. The reaction mixture was stirred for several days before the precipitate was collected on a frit and washed with methanol. The product was then dissolved in Et₂O and 25 stirred over Na₂SO₄ overnight. The solution was filtered through a frit with Celite and the solvent was removed in vacuo to yield the product. The ¹H, ¹³C, and APT spectra are consistent with the existence of the product as the enamine structure shown above: ¹H NMR (CD₂Cl₂, 300 MHz, rt) δ 7.6 - 7.0 (m, 13, Haryl), 6.71 (d, 1, J = 12.1, =CHNHAr), 5.37 (d, 1, J = 12.5, NHAr), 3.34 (septet, 2, J = 6.9, CHMe₂), 1.25 (d, 12, J = 7.0, CHMe₂); ¹³C NMR (CD₂Cl₂, 300 MHz, rt, assignments were aided by an APT spectrum) δ 144.9

(Ar: Co), 142.5, 139.3 and 138.5 (Ar: Cipso, Ph: Cipso, Ph': Cipso), 133.9, 130.9, 129.7, 128.6, 127.1, 126.2, 125.4, 124.7 and 124.0 (Ph: Co, Cm, Cp; Ph': Co, Cm, Cp; Ar: Cm, Cp, Ph₂C=CH), 113.4 (Ph₂C=CH), 28.6 (CHMe₂), 23.9 (CHMe₂).

Examples 209-217

The imines in the following table were synthesized using Procedures A and B below. Details are shown in the Table.

A. Formic acid catalyst was added to a methanol solution of the aldehyde and the aniline. The reaction mixture was stirred and the resulting precipitate was collected on a frit and washed with methanol. The product was then dissolved in Et₂O or CH₂Cl₂ and stirred over Na₂SO₄ overnight. The solution was filtered through a frit with Celite and the solvent was removed in vacuo to yield the product.

B. A CH₂Cl₂ solution of the aldehyde and the aniline was stirred over sodium sulfate. The solution was filtered through a frit with Celite and the solvent was removed in vacuc. If necessary, the product was purified by heating in vacuo to remove excess aniline and/or by recrystallization.

20

| Example | Ligand | Synthesis and NMR Data |
|---------|--------|---|
| 209 | | <p>Procedure A. ¹H NMR (CDCl₃, 300 MHz, rt) δ 8.97 (s, 1, CH=N), 8.43 (dd, 1, J = 7.8, 1.6, Haryl), 7.64 (dd, 1, J = 7.6, 1.3, Haryl), 7.55 (t, 1, J = 7.2, Haryl), 7.46 (td, 1, J = 7.4, 1.7, Haryl), 7.37 (s, 2, Haryl), 1.37 (s, 9, CMe₃), 1.28 (s, 18, CMe₃), 1.21 (s, 9, CMe₃).</p> |
| 210 | | <p>Procedure A. ¹H NMR (CDCl₃, 300 MHz, rt) δ 15.30 (s, 1, OH), 9.09 (s, 1, N=CH), 8.1 - 7.2 (m, 9, Haryl), 3.12 (septet, 2, CHMe₂), 1.25 (d, 12, CHMe₂); ¹³C NMR (CDCl₃, 75 MHz, rt) δ 161.7 (C=N).</p> |

| | | |
|-----|--|---|
| 211 | | Procedure A. ^1H NMR (CDCl_3 , 300 MHz, rt) δ 15.3 (s, 1, OH), 9.23 (s, 1, N=CH), 8.4 - 7.1 (m, 9, Haryl), 2.41 (s, 6, Me). |
| 212 | | Procedure A. ^1H NMR (CDCl_3 , 300 MHz, rt) δ 14.15 (s, 1, OH), 8.43 (s, 1, N=CH), 7.7 - 7.1 (m, 5, Haryl), 2.35 (s, 6, Me). |
| 213 | | Procedure A. ^1H NMR (CDCl_3 , 300 MHz, rt) δ 12.27 (s, 1, OH), 8.85 (N=CH), 7.6 - 6.9 (m, 4, Haryl); ^{13}C NMR (CDCl_3 , 75 MHz, rt) δ 170.6, 161.5, 134.9, 133.3, 119.5, 118.7 and 117.8 (N=CH, Caryl excluding C_6F_5 resonances). |
| 214 | | Procedure A. ^1H NMR (CDCl_3 , 300 MHz, rt) δ 8.20 (s, 1, N=CH), 8.0 - 7.0 (m, 8, Haryl), 3.00 (septet, 2, CHMe_2), 1.21 (d, 12, CHMe_2); ^{13}C NMR (CDCl_3 , 75 MHz, rt) δ 161.9 (N=CH), 149.3, 137.6, 136.1, 131.3, 128.8, 128.5, 124.1 and 123.0 (Caryl), 28.0 (CHMe_2), 23.5 (CHMe_2). |
| 215 | | Procedure A. ^1H NMR (CDCl_3 , 300 MHz, rt) δ 8.48 (s, 1, N=CH), 7.35 - 6.95 (m, 3, Haryl), 2.22 (s, 3, Me); ^{13}C NMR (CDCl_3 , 300 MHz, rt) δ 153.9 (N=CH), 148.2, 130.4, 128.8, 127.6, 125.5 and 122.6 (Caryl excluding C_6F_5 resonances), 18.4 (Me). |

| | | |
|-----|--|--|
| 216 | | <p>Procedure B. ^1H NMR (CDCl_3, 300 MHz, rt) δ 7.99 (s, 1, $\text{CH}=\text{N}$), 7.7 - 6.5 (m, 6, Haryl), 3.00 (septet, 2, CHMe_2), 1.19 (d, 12, CHMe_2); ^{13}C NMR (CDCl_3, 75 MHz, rt) δ 152, 150.4, 149, 145.5, 137.8, 124.3, 123.0, 115.0 and 112.0 (N=CH and Caryl), 27.9 (CHMe_2), 23.6 (CHMe_2).</p> |
| 217 | | <p>Procedure B. ^1H NMR (CDCl_3, 300 MHz, rt) δ 8.35 (s, 1, $\text{CH}=\text{N}$), 7.6 - 7.1 (m, 6, Haryl), 3.08 (septet, 2, CHMe_2), 1.25 (d, 12, CHMe_2); ^{13}C NMR (CDCl_3, 75 MHz, rt) δ 154.9, 148.5, 142.5, 137.8, 131.6, 130.1, 127.6, 124.2 and 122.9 (N=CH and Caryl), 27.9 (CHMe_2), 23.4 (CHMe_2).</p> |

Example 218

In a dry and oxygen free atmosphere, the allyl initiator of Example 168 (16 mg) was dissolved in dry CH_2Cl_2 (2 ml). 5-Ethyldene-2-norbornene (1.8 g) was added. The orange solution 5 warmed and darkened. After stirring for 17 hours the reaction was quenched by addition of methanol and the solid polymer filtered, washed well with methanol and dried. Yield = 1.6 g (89%). $^1\text{H-NMR}$ data confirmed that this was an addition polymer.

Example 219Synthesis of 107

10 2,6-Dimethylthiophenol (3.0 g) was mixed with 30 ml THF. Then 0.87g NaOH was added. The mixture was stirred until all the NaOH has dissolved. THF was removed under vacuum. To the solid 15 was added 40 ml DMF and 4.02 g of the bis toluenesulfonate ester of ethylene glycol. The mixture was refluxed for 5-6 h. DMF was removed by rotary evaporator to give a white residue. Water was added to the residue and the mixture extracted with CH_2Cl_2 . After removing CH_2Cl_2 , a white solid remained. TLC (hexane) showed two bands. The second band from a silica-gel column was the desired 20 product.

$^1\text{H NMR}$ (CDCl_3 , δ in ppm): 2.43 (s, 12H); 2.72 (s, 4H);
7.10 (m, 6H).

Example 220Synthesis of 116

9-Anthrinaldehyde (2.06 g) was dissolved in a minimum amount of THF, then 1.37g anthranilic acid was added. Four drops of formic acid were added as catalyst. The mixture was refluxed for 7h. TLC (5:1 hexane:ethyl acetate) gave 3 bands. The second band is the desired product as determined by ^1H NMR.

Example 221Synthesis of 117

10 10-Chloro-9-anthrinaldehyde (2.41 g) was dissolved in a mixture of 30 ml THF/20 ml CDCl_3 /50 ml toluene. To this boiling solution was added dropwise 3.5g 2,6-diisopropylaniline 3-4 drops of formic acid as a catalyst. The solution was refluxed for 13h. After removing all the solvent, a dark brown thick oil was left. 15 On standing, the oil crystallized. The crystals were washed with methanol.

^1H NMR (CDCl_3 , δ in ppm): 1.40 (d, 12H); 3.35 (p, 2H); 7.40 (m, 3H); 7.75 (m, 4H); 8.75 (d, 2H); 9.05 (d, 2H); 9.55 (s, 1H).

Example 222Synthesis of 118

20 10-Chloro-9-anthrinaldehyde was (2.41 g) was dissolved in 50 ml toluene, and to the hot solution was added 2.0 g of methyl anthranilate (in THF) dropwise. After refluxing for 6h, a yellow solid precipitated. The solid was isolated by filtration, followed by washing with methanol. The solid was dissolved in 2- 25 3ml CDCl_3 and after column separation, golden yellow crystals were obtained. ^1H NMR showed it is a pure product.

30 ^1H NMR (DMF-d₇, δ in ppm): 4.20 (s, 3H); 6.50 (d, 1H); 6.82 (t, 1H); 7.20 (t, 1H); 7.63 (t, 2H); 7.80 (t, 2H); 8.10 (s, 1H); 8.30 (d, 1H); 8.30 (d, 2H); 9.20 (d, 2H).

Example 223

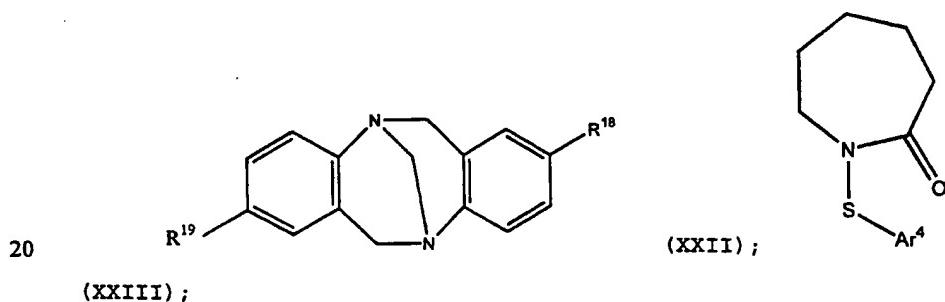
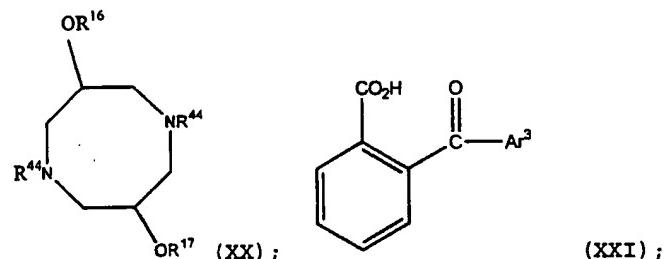
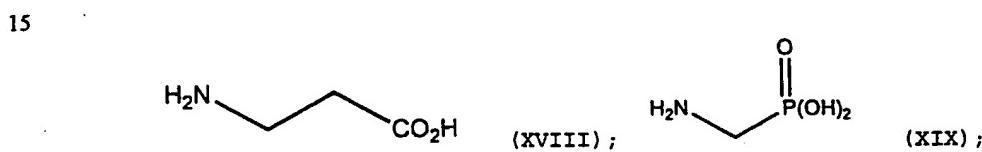
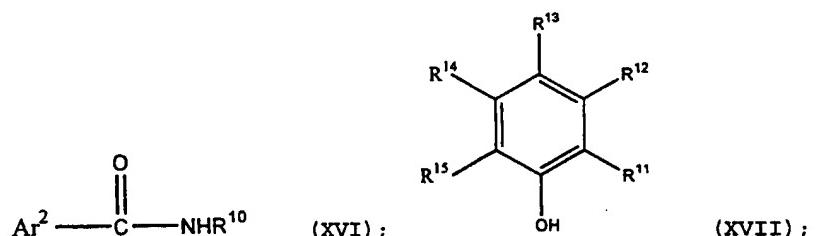
In a dry and oxygen free atmosphere, the allyl initiator of Example 168 (16mg) was dissolved in dry CH_2Cl_2 (2 ml). Dicyclopentadiene (2 ml) was added. The orange solution darkened.

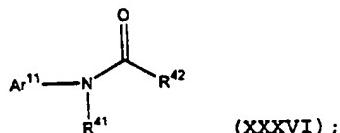
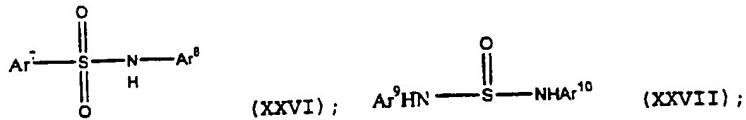
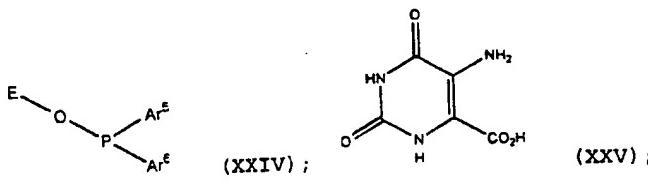
5 After stirring for 72 h the volatiles were removed from the reaction under vacuum. After addition of methanol the solid polymer precipitated and was filtered, washed well with methanol and dried. Yield = 0.29 g (15%). The product was insoluble at room temperature in common organic solvents.

CLAIMS

What is claimed is:

1. A process for the polymerization of an olefin,
comprising:
- 5 (a) contacting a polymerizable monomer consisting
essentially of ethylene, a norbornene or a styrene, and a catalyst
system comprising the product of mixing in solution a zerovalent
tricoordinate or tetracoordinate nickel compound (II) which has at
least one labile ligand, and all ligands are neutral, an acid of
10 the formula HX (IV), and a first compound selected from the group
consisting of:





5 $R^{22}R^{23}R^{24}P$ (XXVIII);
 and $R^8S-CR^4R^5(CR^6R^7)_mSR^6$ (XXXVII);

and wherein:

X is a noncoordinating anion;

Ar¹ is an aromatic moiety with n free valencies, or

10 diphenylmethyl;

each Q is $-NR^2R^{43}$ or $-CR^9=NR^3$;

R^{43} is hydrogen or alkyl;

n is 1 or 2;

E is 2-thienyl or 2-furyl;

15 each R² is independently hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl;

each R⁹ is independently hydrogen or hydrocarbyl; and

each R³ is independently a monovalent aromatic moiety;

m is 1, 2 or 3;

20 each R⁴, R⁵, R⁶, and R⁷ is independently hydrogen,

hydrocarbyl or substituted hydrocarbyl;

each R⁸ is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

each R¹⁰ is independently hydrogen, hydrocarbyl or

25 substituted hydrocarbyl;

Ar² is an aryl moiety;

R¹², R¹³, and R¹⁴ are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

R^{11} and R^{15} are each independently hydrocarbyl, substituted hydrocarbyl or an inert functional group whose E_s is about -0.4 or less;

each R^{16} and R^{17} is independently hydrogen or acyl containing 1 to 20 carbon atoms;

Ar^3 is an aryl moiety;

R^{18} and R^{19} are each independently hydrogen or hydrocarbyl;

Ar^4 is an aryl moiety;

Ar^5 and Ar^6 are each independently hydrocarbyl;

Ar^7 and Ar^8 are each independently an aryl moiety;

Ar^9 and Ar^{10} are each independently an aryl moiety or $-CO_2R^{25}$, wherein R^{25} is alkyl containing 1 to 20 carbon atoms;

Ar^{11} is an aryl moiety;

R^{41} is hydrogen or hydrocarbyl;

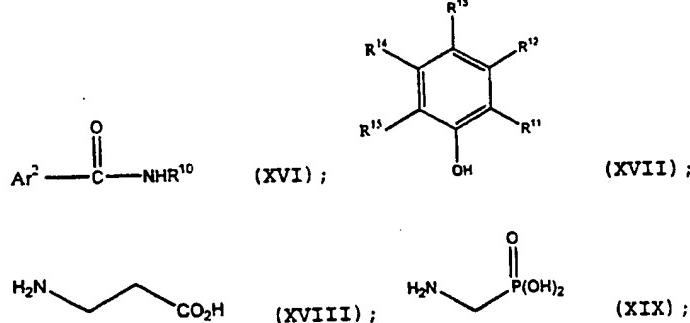
R^{42} is hydrocarbyl or $-C(O)-NR^{41}-Ar^{11}$;

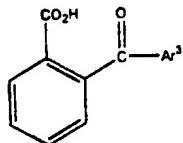
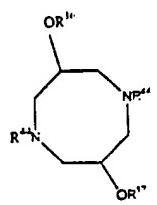
R^{44} is aryl;

R^{22} and R^{23} are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and

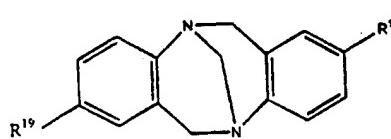
R^{24} is alkyl containing 1 to 20 carbon atoms, or an a moiety.

2. A catalyst for the polymerization of ethylene, a
norbornene, or a styrene, comprising, the product of mixing in
solution a zerovalent tricoordinate or tetracoordinate nickel
compound (II) which has at least one labile ligand and all ligands
are neutral, an acid of the formula HX (IV), and a first compound
selected from the group consisting of:

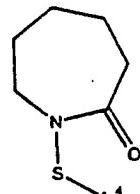




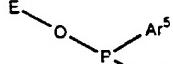
(XXI);



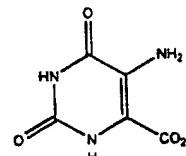
(XXII);



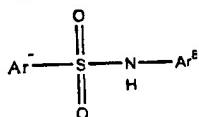
5 (XXIII);



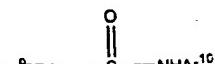
(XXIV);



(XXV);

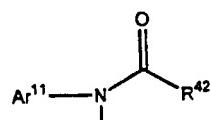


(XXVI);



(XXVII);

10

 $R^{22}R^{23}R^{24}P$ (XXVIII);and $R^8S-CR^4R^5(CR^6R^7)_m-SR^8$ (XXXVII);

and wherein:

X is a noncoordinating anion;

15 Ar¹ is an aromatic moiety with n free valencies, or

diphenylmethyl;

each Q is $-NR^2R^{43}$ or $-CR^9=NR^3$; R^{43} is hydrogen or alkyl

n is 1 or 2;

20 E is 2-thienyl or 2-furyl;

each R^2 is independently hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl;

each R^3 is independently a monovalent aromatic moiety;

each R^9 is independently hydrogen or hydrocarbyl; m is
5 1, 2 or 3;

each R^4 , R^5 , R^6 , and R^7 is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

each R^8 is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

10 each R^{10} is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

Ar^2 is an aryl moiety;

R^{12} , R^{13} , and R^{14} are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

15 R^{11} and R^{15} are each independently hydrocarbyl, substituted hydrocarbyl or an inert functional group whose E_s is about -0.4 or less;

each R^{16} and R^{17} is independently hydrogen or acyl containing 1 to 20 carbon atoms;

20 Ar^3 is an aryl moiety;

R^{18} and R^{19} are each independently hydrogen or hydrocarbyl;

Ar^4 is an aryl moiety;

Ar^5 and Ar^6 are each independently hydrocarbyl;

25 Ar^7 and Ar^8 are each independently an aryl moiety;

Ar^9 and Ar^{10} are each independently an aryl moiety, - CO_2R^{25} , or Ar^7 and Ar^8 taken together are a divalent aromatic moiety and wherein R^{25} is alkyl containing 1 to 20 carbon atoms;

Ar^{11} is an aryl moiety;

30 R^{41} is hydrogen or hydrocarbyl;

R^{42} is hydrocarbyl or -C(O)-NR⁴¹-Ar¹¹;

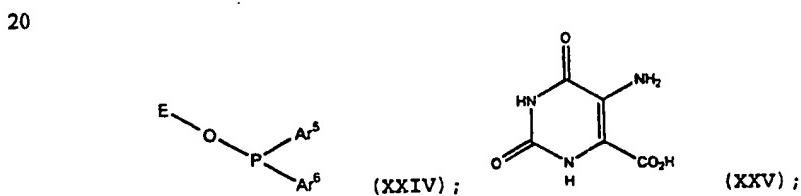
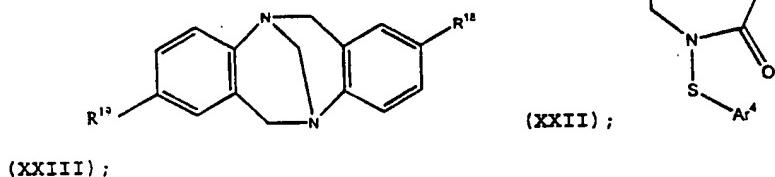
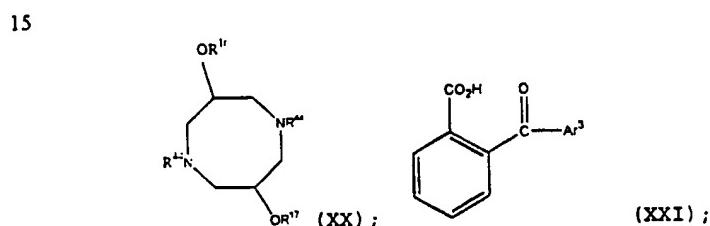
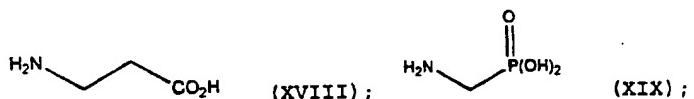
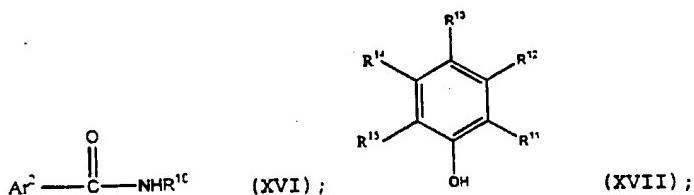
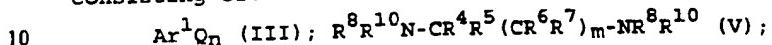
R^{22} and R^{23} are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and

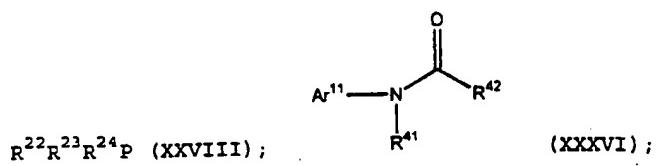
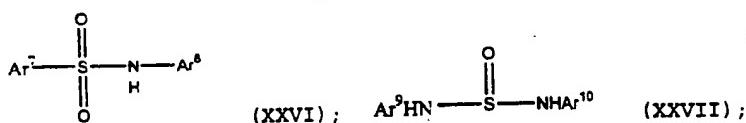
35 R^{24} is alkyl containing 1 to 20 carbon atoms, or an aryl moiety;

R^{44} is aryl;

and provided that the molar ratio of (III), (V) (XVI), (XVII), (XVIII), (XIX), (XX), (XXI), (XXII), (XXIII), (XXIV), (XXV), (XXVI), (XXVII), (XXVIII), (XXXVI) or (XXXVII):(II) is about 0.5 to about 5, and the molar ratio of (IV):(II) is about 5. 0.5 to about 10.

3. A process for the polymerization of an olefin, comprising, contacting ethylene, a norbornene, or a styrene with a nickel [II] complex of a first compound selected from the group consisting of:





5 and wherein:

X is a noncoordinating anion;

Ar^1 is an aromatic moiety with n free valencies, or diphenylmethyl;

each Q is $-\text{NR}^2\text{R}^{43}$ or $-\text{CR}^9=\text{NR}^3$;

10 R^{42} is hydrogen or alkyl

n is 1 or 2;

E is 2-thienyl or 2-furyl;

each R^2 is independently hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl;

15 each R^3 is independently a monovalent aromatic moiety;
each R^9 is independently hydrogen or hydrocarbyl; m is 1, 2 or 3;

each R^4 , R^5 , R^6 , and R^7 is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

20 each R^8 is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

each R^{10} is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;

Ar^2 is an aryl moiety;

25 R^{12} , R^{13} , and R^{14} are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

R^{11} and R^{15} are each independently hydrocarbyl, substituted hydrocarbyl or an inert functional group whose E_s is about -0.4 or less;

30 each R^{16} and R^{17} is independently hydrogen or acyl containing 1 to 20 carbon atoms;

Ar^3 is an aryl moiety;

R^{18} and R^{19} are each independently hydrogen or hydrocarbyl;

Ar⁴ is an aryl moiety;

Ar⁵ and Ar⁶ are each independently hydrocarbyl;

Ar⁷ and Ar⁸ are each independently an aryl moiety;

Ar⁹ and Ar¹⁰ are each independently an aryl moiety, -

CO_2R^{25} , or Ar⁷ and Ar⁸ taken together are a divalent aromatic moiety and wherein R²⁵ is alkyl containing 1 to 20 carbon atoms;

Ar¹¹ is an aryl moiety;

10 R⁴¹ is hydrogen or hydrocarbyl;

R⁴² is hydrocarbyl or -C(O)-NR⁴¹-Ar¹¹;

R⁴⁴ is aryl;

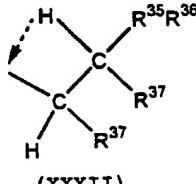
15 R²² and R²³ are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms, and

R²⁴ is alkyl containing 1 to 20 carbon atoms, or an aryl moiety.

4. A process for the polymerization of olefins, comprising, contacting ethylene, a norbornene or a styrene with a nickel 20 containing first compound of the formula $[L^1_q L^2_r L^3_s L^4_t Ni]^{+} X^{-}$ (XXXIII), wherein:

25 L¹ is a first monodentate neutral ligand coordinated to said nickel, L² is a second monodentate neutral ligand coordinated to said nickel which may be said first monodentate neutral ligand and r is 0 or 1, or L¹ and L² taken together are a first bidentate neutral ligand coordinated to said nickel and r is 1;

L³ and L⁴ taken together are a π -allyl ligand coordinated to said nickel, L³ and L⁴ taken together are



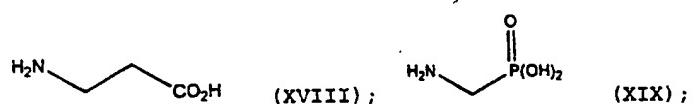
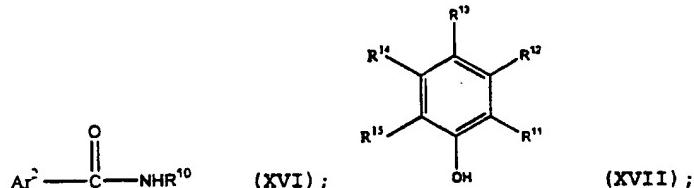
30 (XXXII)

coordinated to said nickel, or L³ is a third neutral monodentate ligand selected from the group consisting of ethylene, a norbornene and a styrene or a neutral monodentate ligand which can be displaced by an olefin, and L⁴ is R³⁸;

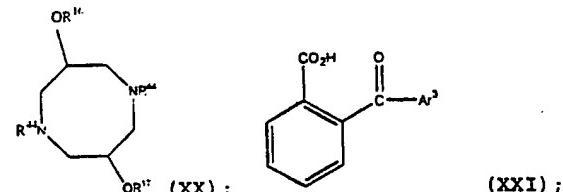
35 q, s and t are each 1;

X is a relatively non-coordinating anion;
 said first monodentate neutral ligand and said first
 bidentate neutral ligand are selected from the group consisting of
 Ar^1Q_n (III); $\text{R}^8\text{R}^{10}\text{N-CR}^4\text{R}^5(\text{CR}^6\text{R}^7)_m\text{-NR}^8\text{R}^{10}$ (V);

5

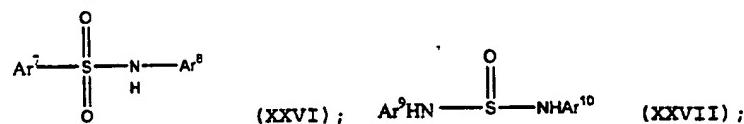
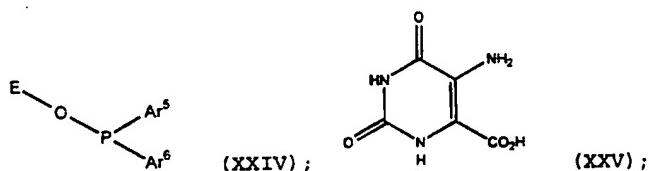


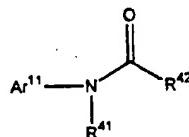
10



(XXIII);

15





$R^{22}R^{23}R^{24}P$ (XXVIII); (XXXVI);

and $R^6S-CR^4R^5(CR^6R^7)_m-SR^6$ (XXXVII);

Ar^1 is an aromatic moiety with n free valencies, or

diphenylmethyl;

5 each Q is $-NR^2R^{43}$ or $-CR^9=NR^3$;

R^{43} is hydrogen or alkyl

n is 1 or 2;

E is 2-thienyl or 2-furyl;

each R^2 is independently hydrogen, benzyl, substituted

10 benzyl, phenyl or substituted phenyl;

each R^9 is independently hydrogen or hydrocarbyl; and

each R^3 is independently a monovalent aromatic moiety;

m is 1, 2 or 3;

each R^4 , R^5 , R^6 , and R^7 is independently hydrogen,

15 hydrocarbyl or substituted hydrocarbyl;

each R^8 is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;

each R^{10} is independently hydrogen, hydrocarbyl or

substituted hydrocarbyl;

20 Ar^2 is an aryl moiety;

R^{12} , R^{13} , and R^{14} are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

R^{11} and R^{15} are each independently hydrocarbyl,

substituted hydrocarbyl or an inert functional group whose E_s is

25 about -0.4 or less;

each R^{16} and R^{17} is independently hydrogen or acyl containing 1 to 20 carbon atoms;

Ar^3 is an aryl moiety;

30 R^{18} and R^{19} are each independently hydrogen or

hydrocarbyl;

Ar^4 is an aryl moiety;

Ar^5 and Ar^6 are each independently hydrocarbyl;

Ar^7 and Ar^8 are each independently an aryl moiety;

Ar^9 and Ar^{10} are each independently an aryl moiety or

35 $-CO_2R^{25}$, wherein R^{25} is alkyl containing 1 to 20 carbon atoms;

Ar^{11} is an aryl moiety;

R^{41} is hydrogen or hydrocarbyl;

R^{42} is hydrocarbyl or $-\text{C}(\text{O})-\text{NR}^{41}-\text{Ar}^{11}$;

R^{22} and R^{23} are each independently phenyl groups

5 substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and

R^{24} is alkyl containing 1 to 20 carbon atoms, or an aryl moiety;

R^{35} is hydrocarbylene;

10 R^{36} is hydrogen, alkyl, or $-\text{C}(\text{O})\text{R}^{39}$;

each R^{37} is hydrocarbyl or both of R^{37} taken together are hydrocarbylene to form a carbocyclic ring;

R^{38} is hydride, alkyl or $-\text{C}(\text{O})\text{R}^{39}$;

R^{39} is hydrocarbyl; and

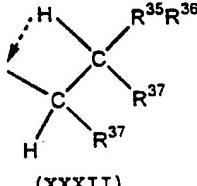
15 R^{44} is aryl.

5. A compound of the formula $[\text{L}^1_q\text{L}^2_r\text{L}^3_s\text{L}^4_t\text{Ni}]^+\text{X}^-$ (XXXIII),

wherein:

1 L¹ is a first monodentate neutral ligand coordinated to said nickel, L² is a second monodentate neutral ligand coordinated to said nickel which may be said first monodentate neutral ligand and r is 0 or 1, or L¹ and L² taken together are a first bidentate neutral ligand coordinated to said nickel and r is 1;

20 L³ and L⁴ taken together are a π -allyl ligand coordinated to said nickel, L³ and L⁴ taken together are



25

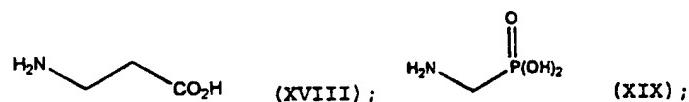
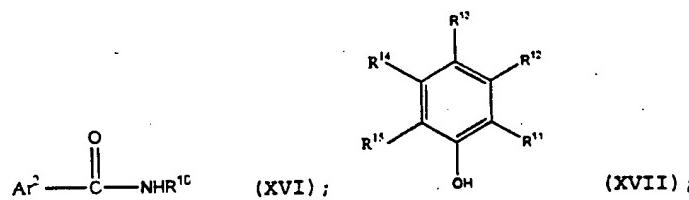
(XXXII)

coordinated to said nickel, or L³ is a third neutral monodentate ligand selected from the group consisting of ethylene, a norbornene and a styrene or a neutral monodentate ligand which can 30 be displaced by an olefin, and L⁴ is R³⁸;

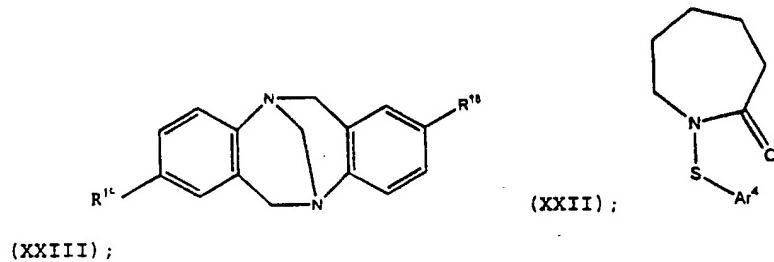
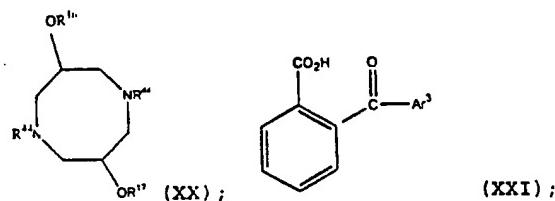
X is a relatively non-coordinating anion;

q, s and t are each 1;

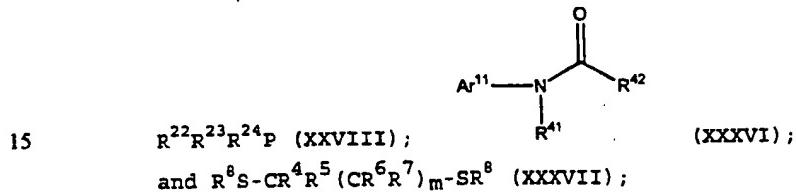
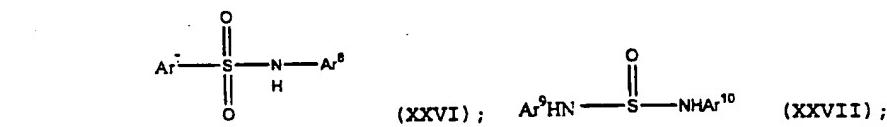
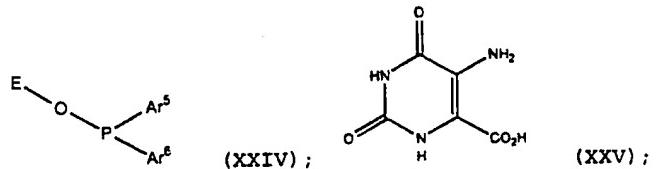
35 said first monodentate neutral ligand and said first bidentate neutral ligand are selected from the group consisting of Ar^1Q_n (III); $\text{R}^8\text{R}^{10}\text{N}-\text{CR}^4\text{R}^5(\text{CR}^6\text{R}^7)_m-\text{NR}^8\text{R}^{10}$ (V);



5



10



Ar¹ is an aromatic moiety with n free valencies, or diphenylmethyl;
each Q is -NR²R⁴³ or -CR⁹=NR³;
R⁴³ is hydrogen or alkyl
5 n is 1 or 2;
E is 2-thienyl or 2-furyl;
each R² is independently hydrogen, benzyl, substituted benzyl, phenyl or substituted phenyl;
each R⁹ is independently hydrogen or hydrocarbyl; and
10 each R³ is independently a monovalent aromatic moiety;
m is 1, 2 or 3;
each R⁴, R⁵, R⁶, and R⁷ is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;
each R⁸ is independently hydrocarbyl or substituted hydrocarbyl containing 2 or more carbon atoms;
15 each R¹⁰ is independently hydrogen, hydrocarbyl or substituted hydrocarbyl;
Ar² is an aryl moiety;
R¹², R¹³, and R¹⁴ are each independently hydrogen,
20 hydrocarbyl, substituted hydrocarbyl or an inert functional group;
R¹¹ and R¹⁵ are each independently hydrocarbyl, substituted hydrocarbyl or an inert functional group whose E_s is about -0.4 or less;
each R¹⁶ and R¹⁷ is independently hydrogen or acyl
25 containing 1 to 20 carbon atoms;
Ar³ is an aryl moiety;
R¹⁸ and R¹⁹ are each independently hydrogen or hydrocarbyl;
Ar⁴ is an aryl moiety;
30 Ar⁵ and Ar⁶ are each independently hydrocarbyl;
Ar⁷ and Ar⁸ are each independently an aryl moiety;
Ar⁹ and Ar¹⁰ are each independently an aryl moiety or -CO₂R²⁵, wherein R²⁵ is alkyl containing 1 to 20 carbon atoms;
Ar¹¹ is an aryl moiety;
35 R⁴¹ is hydrogen or hydrocarbyl;
R⁴² is hydrocarbyl or -C(O)-NR⁴¹-Ar¹¹;
R⁴⁴ is aryl;

R²² and R²³ are each independently phenyl groups substituted by one or more alkoxy groups, each alkoxy group containing 1 to 20 carbon atoms; and
R²⁴ is alkyl containing 1 to 20 carbon atoms, or an aryl

5 moiety;

R³⁵ is hydrocarbylene;

R³⁶ is hydrogen, alkyl, or -C(O)R³⁹;

each R³⁷ is hydrocarbyl or both of R³⁷ taken together are hydrocarbylene to form a carbocyclic ring;

10 R³⁸ is hydride, alkyl or -C(O)R³⁹; and

R³⁹ is hydrocarbyl.

6. The process as recited in claim 1 or 3 wherein the molar ratio of (III):(II) is about 0.5 to 5, and the molar ratio of (IV):(II) is about 0.5 to about 10.

15 7. The process or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein X is BF₄⁻, PF₆⁻, BAF⁻ or SbF₆⁻.

8. The process or catalyst as recited in claim 1, 2 or 3 wherein (II) is bis(η^4 -1,5-cyclooctadienyl)nickel[0].

9. The process as recited in claim 1, 3 or 4 wherein an 20 olefin is ethylene.

10. The process as recited in claim 1, 3 or 4 wherein an olefin is norbornene.

11. The process as recited in claim 1, 3 or 4 wherein an olefin is styrene.

15 12. The process as recited in claim 1, 3 or 4 wherein an olefin is a combination of styrene and norbornene, and a copolymer of styrene and norbornene is produced.

13. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate 30 neutral ligand is (III).

14. The process, compound or catalyst as recited in claim 13 wherein:

n is 1, Q is -CR⁹=NR³, R⁹ is hydrogen, Ar¹ is 9-anthracenyl, and R³ is 2-carbamoylphenyl or 2,6-diisopropylphenyl;
35 n is 2 and Q is -CR⁹=NR³, R³ is 2,6-disubstituted phenyl in which substituents are halo, alkyl, or halo and alkyl, Ar¹ is p-phenylene, and R⁹ is hydrogen;

n is 1, Q is $-CR^9=NR^3$, R⁹ is hydrogen, R³ is 2,6-dimethylphenyl, and Ar¹ is pentafluorophenyl; or

n is 1, Q is $-CR^9=NR^3$, R⁹ is hydrogen, R³ is 2,6-diisopropylphenyl, and Ar¹ is 2-hydroxy-1-naphthyl.

5 15. The process, compound or catalyst as recited in claim 13

wherein:

n is 1, Q is $-NR^2R^{43}$, R² is $-CH=CPh_2$, R⁴³ is hydrogen, and Ar¹ is 2,6-diisopropylphenyl;

10 n is 1, Q is $-NR^2R^{43}$, R² is $-CH=CPh_2$, R⁴³ is hydrogen and Ar¹ is 2-carbamoylphenyl;

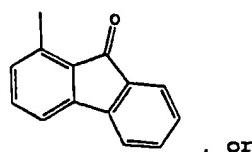
n is 2, Q is $-NR^2R^{43}$, R² is hydrogen, R⁴³ is hydrogen, and Ar¹ is 1,8-naphthylene;

15 n is 1, Q is $-NR^2R^{43}$, R² is $-CH=CPh_2$, R⁴³ is hydrogen, and Ar¹ is 2-methoxycarbonylphenyl;

n is 1, Q is $-NR^2R^{43}$, R² is hydrogen, R⁴³ is hydrogen, and Ar¹ is 2-carboxyphenyl;

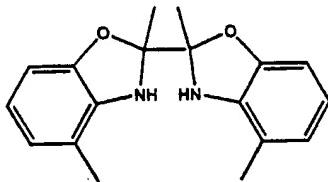
n is 1, Q is $-NR^2R^{43}$, R² is $-CH=CPh_2$, R⁴³ is hydrogen, and Ar¹ is 1-anthraquinonyl;

20 n is 1, Q is NR^2R^{43} , R² is $-CH=CPh_2$, R⁴³ is hydrogen, and Ar¹ is



, or

wherein (III) is



16. The process, compound or catalyst as recited in claim 1,
25 2, 3, 4 or 5 wherein said first compound or said first monodentate
neutral ligand is (V).

17. The process or catalyst as recited in claim 16 wherein:

m is 1, all of R⁸, R⁴, R⁵, R⁶ and R⁷ are hydrogen, and both of R¹⁰ are 2,6-diisopropylphenyl; or

30 m is 1, all of R⁸, R⁴, R⁵, R⁶ and R⁷ are hydrogen, and both of R¹⁰ are cyclohexyl.

18. The process, compound or catalyst as recited in claim 1,
2, 3, 4 or 5 wherein said first compound or said first monodentate
neutral ligand is (XVI).

19. The process or catalyst as recited in claim 18 wherein:
5 Ar² is 2-(N-2,2-diphenylethenylamino)phenyl and R¹⁰ is
hydrogen;

Ar² is phenyl and R¹⁰ is 2,6-diisopropylphenyl;

Ar² is 2-pyridyl and R¹⁰ is hydrogen; or

Ar² is 3-hydroxy-2-pyridyl and R¹⁰ is hydrogen.

10 20. The process, compound or catalyst as recited in claim 1,
2, 3, 4 or 5 wherein said first compound or said first monodentate
neutral ligand is (XVII).

21. The process, compound or catalyst as recited in claim 20
wherein:

15 R¹¹ and R¹⁵ are t-butyl and R¹², R¹³ and R¹⁴ are hydrogen;

R¹¹, R¹³ and R¹⁵ are t-butyl and R¹² and R¹⁴ are hydrogen;

R¹¹ and R¹⁵ are phenyl and R¹², R¹³ and R¹⁴ are hydrogen;

or

20 R¹¹ is t-butyl and R¹² and R¹⁴ are hydrogen, R¹³ is
methoxy, and R¹⁵ is 2-hydroxy-3-t-butyl-5-methoxyphenyl.

22. The process, compound or catalyst as recited in claim 1,
2, 3, 4 or 5 wherein said first compound or said first monodentate
neutral ligand is (XVIII).

23. The process, compound or catalyst as recited in claim 1,
25 2, 3, 4 or 5 wherein said first compound or said first monodentate
neutral ligand is (XIX).

24. The process, compound or catalyst as recited in claim 1,
2, 3, 4 or 5 wherein said first compound or said first monodentate
neutral ligand is (XX) both of R⁴⁴ are phenyl.

30 25. The process, compound or catalyst as recited in claim 24
wherein:

both of R¹⁶ and R¹⁷ are hydrogen; or

both of R¹⁶ and R¹⁷ are acetyl.

26. The process, compound or catalyst as recited in claim 1,
35 2, 3, 4 or 5 wherein said first compound or said first monodentate
neutral ligand is (XXI).

27. The process, compound or catalyst as recited in claim 26
wherein Ar³ is 2-aminophenyl.

28. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXII).

29. The process, compound or catalyst as recited in claim 28 5 wherein R¹⁸ and R¹⁹ are both methyl or both hydrogen.

30. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXIII).

31. The process, compound or catalyst as recited in claim 30 10 wherein Ar⁴ is phenyl.

32. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXIV).

33. The process, compound or catalyst as recited in claim 32 15 wherein both of Ar⁵ and Ar⁶ are phenyl or wherein both of Ar⁵ and Ar⁶ are cyclohexyl.

34. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXV).

35. The process, compound or catalyst as recited in claim 1, 20 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXVI).

36. The process, compound or catalyst as recited in claim 35 25 wherein Ar⁷ is p-tolyl or phenyl and Ar⁸ is 2,6-diisopropylphenyl.

37. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate 30 neutral ligand is (XXVII).

38. The process, compound or catalyst as recited in claim 37 wherein:

Ar⁹ and Ar¹⁰ taken together are 1,8-naphthylene; or
Ar⁹ is -CO₂CH₃ and Ar¹⁰ is



39. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXVIII).

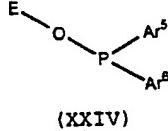
40. The process, compound or catalyst as recited in claim 39
5 wherein:

all of R²², R²³ and R²⁴ are 2,4,6-trimethoxyphenyl;
both of R²² and R²³ are 2,3,6-trimethoxyphenyl and R²⁴ is ethyl;
all of R²², R²³ and R²⁴ are 2,6-dimethoxyphenyl; or
10 both of R²² and R²³ are 2,3,6-trimethoxyphenyl and R²⁴ is isopropyl.

41. The process, compound or catalyst as recited in claim 39
wherein at least one of R²², R²³ and R²⁴ is substituted and that a
sum of σ and σ* constants for at least one of R²², R²³ and R²⁴ is
15 about -0.50 or less.

42. The process, compound or catalyst as recited in claim 41
wherein R²⁴ is an aryl moiety, all of R²², R²³ and R²⁴ are
substituted, and said sum of said σ and σ* constants for each of
R²², R²³ and R²⁴ is about -0.50 or less.

20 43. A compound of the formula



wherein:

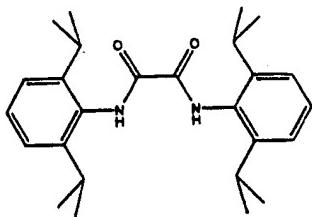
E is 2-thienyl or 2-furyl;
25 Ar⁵ and Ar⁶ are each independently hydrocarby.
44. The compound as recited in claim 43 wherein both of Ar⁵ and Ar⁶ are phenyl or wherein both of Ar⁵ and Ar⁶ are cyclohexyl.

45. The process as recited in claim 3 or 4 carried out in a solvent.

30 46. The process as recited in claim 1, 3 or 4 carried out at a temperature of about -20°C to about 100°C.

47. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXXVI).

35 48. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein (XXXVI) is



49. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein said first compound or said first monodentate neutral ligand is (XXXVII).

50. The process, compound or catalyst as recited in claim 49 wherein both of R⁸ are aryl moieties and all of R⁴, R⁵, R⁶, R⁷ and R⁸ are hydrogen.

51. The process as recited in claim 50 wherein both of R⁸ are 2,6-dimethylphenyl.

52. The process, compound or catalyst as recited in claim 1, 2, 3, 4 or 5 wherein X is BAF.

53. The process or compound as recited in claim 4 or 5 wherein r is 1.

54. The process or compound as recited in claim 4 or 5 wherein r is 0.

55. The process or compound as recited in claim 54 wherein (XXXIII) is a dimer with bridging L¹ ligands.

56. The process, compound or catalyst as recited in claim 13 wherein:

20 n is 2

Q is -CR⁹=NR³;

Ar¹ is diphenylmethyl; R⁹ is hydrogen

and R³ is selected from the group consisting of 2,6-diisopropylphenyl, 2-carbamoylphenyl, 2-methoxycarbonylphenyl, 1-anthraquinolyl, 2,6-dimethylphenyl and 1-fluoren-9-onyl.

25 57. The process as recited in claim 3 wherein said nickel [II] complex is a π-allyl complex.

58. The process as recited in claim 4 wherein L³ and L⁴ taken together are a π-allyl group.

30 59. The compound as recited in claim 5 wherein L³ and L⁴ taken together are a π-allyl group.

60. The process as recited in claim 57 or 58 wherein a Lewis acid is also present.

61. The process as recited 1, 3 or 4 wherein at least 2 or more norbornenes are present, to form a copolymer.

62. The process as recited in claim 1, 3 or 4 wherein at least 2 or more styrenes are present to form a copolymer.

5 63. The process as recited in claim 1, 3 or 4 wherein at least one styrene and at least norbornene are present to form a copolymer.

64. The process as recited in claim 61 wherein a nobornene present is 5-ethylidene-2-norbonene.

INTERNATIONAL SEARCH REPORT

Int'l Application No
PCT/US 96/11131

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|-------------------------------------|-----------|-----------|-----------|----------|
| A. CLASSIFICATION OF SUBJECT MATTER | | | | |
| IPC 6 | C08F10/02 | C08F12/04 | C08F32/04 | C08F4/70 |

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C08F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|---|------------------------|
| X | JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, vol. 117, no. 23, 14 June 1995, WASHINGTON, XP002015954 JOHNSON, L. K. ET AL.: "New Pd(II)- and Ni(II)-Based Catalysts for Polymerization of Ethylene and alpha-Olefins" see page 6414 - page 6415 --- | 1-9 |
| X | MACROMOLECULAR SYMPOSIA, vol. 89, 1 January 1995, pages 393-409, XP000509182 TAUBE R ET AL: "THE CATALYSIS OF THE STEREOSPECIFIC BUTADIENE POLYMERIZATION BY ALLYL NICKEL AND ALLYL LANTHANIDE COMPLEXES A MECHANISTIC COMPARISON" | 5 |
| A | --- | 1-4, 6-42, 45-64 |
| | -/- | |

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

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- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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|---|--|
| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|--|

15 October 1996

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| Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl. Fax: (+31-70) 340-3016 | Authorized officer |
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Kaumann, E

INTERNATIONAL SEARCH REPORT

Int'l Application No
PCT/US 96/11131

C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| Y | EP 0 454 231 A (UNIV NORTH CAROLINA) 30 October 1991 see the whole document --- | 1-42, 45-64 |
| Y | US 5 198 512 A (JACKSON MARGIE F ET AL) 30 March 1993 see the whole document --- | 1-42, 45-64 |
| X | WO 95 14048 A (GOODRICH CO B F) 26 May 1995 see the whole document --- | 5,7,8, 10,12 |
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| A | US 4 716 205 A (KLABUNDE ULRICH) 29 December 1987 see the whole document ----- | 1-64 |

INTERNATIONAL SEARCH REPORT

Information on patent family members

| |
|----------------------|
| Int'l Application No |
| PCT/US 96/11131 |

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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| EP-A-0454231 | 30-10-91 | CA-A- 2040808 JP-A- 4227608 US-A- 5516739 | 21-10-91 17-08-92 14-05-96 |
| US-A-5198512 | 30-03-93 | AT-T- 140462 CA-A- 2085558 CN-A,B 1073452 DE-D- 69212291 EP-A- 0548753 JP-A- 5239143 US-A- 5328881 | 15-08-96 17-06-93 23-06-93 22-08-96 30-06-93 17-09-93 12-07-94 |
| WO-A-9514048 | 26-05-95 | US-A- 5468819 AU-A- 1179195 CA-A- 2174756 EP-A- 0729480 | 21-11-95 06-06-95 26-05-95 04-09-96 |
| DE-A-1793788 | 21-11-74 | NONE | |
| DE-A-4415725 | 10-11-94 | FR-A- 2704859 | 10-11-94 |
| US-A-5332794 | 26-07-94 | JP-A- 5295014 | 09-11-93 |
| US-A-3676523 | 11-07-72 | BE-A- 786282 CA-A- 995257 DE-A- 2234734 FR-A- 2146276 GB-A- 1353873 NL-A- 7209668 | 15-01-73 17-08-76 25-01-73 02-03-73 22-05-74 18-01-73 |
| US-A-4716205 | 29-12-87 | NONE | |